# TECHNICAL SUPPORT DOCUMENT FOR ESTABLISHMENT OF A SUSPENDED SEDIMENT TOTAL MAXIMUM DAILY LOAD FOR THE PAJARO RIVER WATERSHED

*FINAL*

**MAY 2004**

Prepared by Tetra Tech, Inc.
10306 Eaton Place, Suite 340
Fairfax, VA 22030

for

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD Central Coast Region

895 Aerovista Place
Suite 101
San Luis Obispo, CA 93401

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# 1.0 INTRODUCTION

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based pollution controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollutant sources and in-stream water quality conditions so that states can establish water quality-based controls to reduce pollutant loading and restore and maintain the quality of water resources (USEPA 1991).

Five waterbodies in the Pajaro River watershed have been placed on the 1998 Section 303(d) list due to sedimentation/siltation impairments.

## 1.1 Watershed Description

The Pajaro River watershed encompasses approximately 1,263 square miles (807,940 acres). It is about 60 miles southeast of San Francisco and Oakland and 120 miles southwest of Sacramento (Figure 1-1). The watershed is almost 90 miles in length and varies from 7 to 20 miles in width. The Pajaro River watershed drains into the Monterey Bay and is the largest coastal stream between San Francisco Bay and the Salinas River.

The watershed lies within Monterey, San Benito, Santa Cruz, and Santa Clara counties. The city of Watsonville is located in the watershed near the confluence of the Pajaro River with Monterey Bay. Major tributaries in the watershed are the San Benito River, Tres Pinos Creek, Santa Ana Creek, Pacheco Creek, Llagas Creek, Uvas Creek, and Corralitos Creek. The watershed is predominantly mountainous and hilly, and level lands are confined to the floodplains of the Pajaro River and its major tributaries (San Jose State University 1994). Elevations in the watershed range from sea level where the Pajaro River enters the Monterey Bay to over 4,900 feet in the headwaters of the San Benito River.

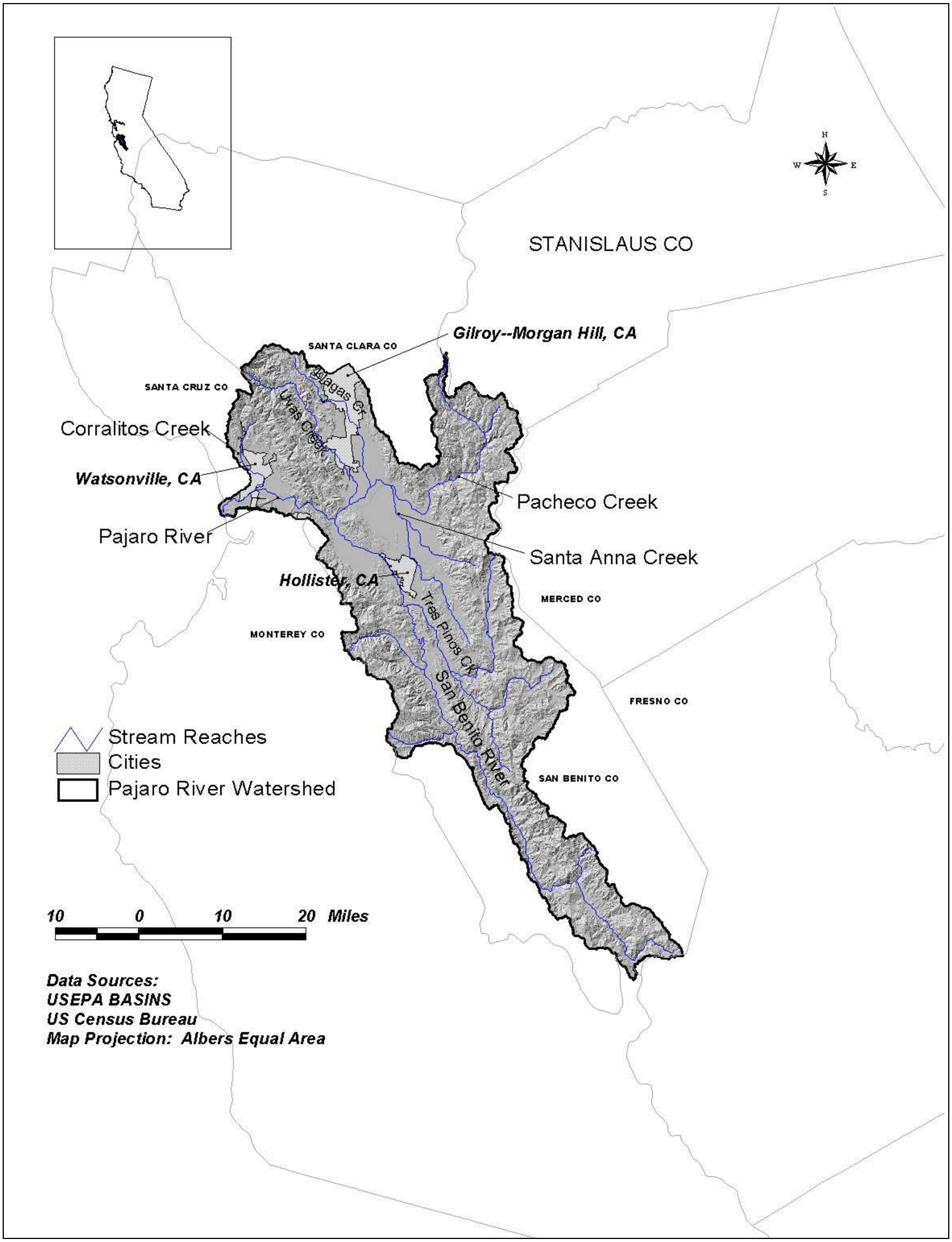



Figure 1-1. Location of the Pajaro River watershed.

## 1.2 Impairment Overview

A 49-mile segment of the Pajaro River was included on California's 1998 Section 303(d) list as impaired by sedimentation/siltation from agriculture, irrigated crop production, rangeland, agriculture-storm runoff, resource extraction, surface mining, hydromodification, channelization, habitat modification, removal of riparian vegetation, streambank modification, and channel erosion. The 303(d) list indicates that this segment was given medium priority for TMDL development. The same segment of the Pajaro River is also listed as impaired by nutrients from similar sources. Staff members from the Central Coast Regional Water Quality Control Board (RWQCB) are developing the nutrient TMDLs for the Pajaro River.

In addition to the Pajaro River, four more waterbodies in the watershed are listed on the 1998 Section 303(d) list as impaired by sediment/siltation (Figure 1-2), as summarized in Table 1-1.

Table 1-1. Waterbodies on 1998 Section 303(d) List, Pajaro River Watershed

| Waterbody | Cause | Source | Priority | Size |
|---|---|---|---|---|
| **Pajaro River** | Sedimentation/siltation | Sedimentation/siltation from agriculture, irrigated crop production, rangeland, agriculture-storm runoff, resource extraction, surface mining, hydromodification, channelization, habitat modification, removal of riparian vegetation, streambank modification, and channel erosion | Medium | 32 miles |
| **Llagas Creek** | Sedimentation/siltation | Agriculture, hydromodification, habitat modification | High | 16 miles |
| **Rider Gulch Creek** | Sedimentation/siltation | Agriculture, silviculture, construction/land development | Medium | 2 miles |
| **San Benito River** | Sedimentation/siltation | Agriculture, resource extraction, nonpoint sources | Medium | 86 miles |
| **Watsonville Slough** [a] | Sedimentation/siltation | Agriculture, Irrigated Crops, Agriculture-storm runoff, nonpoint sources | Medium | 300 acres |

[a] Though tributary to the Pajaro River, the Watsonville Slough system is not included in this sediment TMDL. A sediment TMDL specific to the Watsonville Slough system will be completed as a separate project.

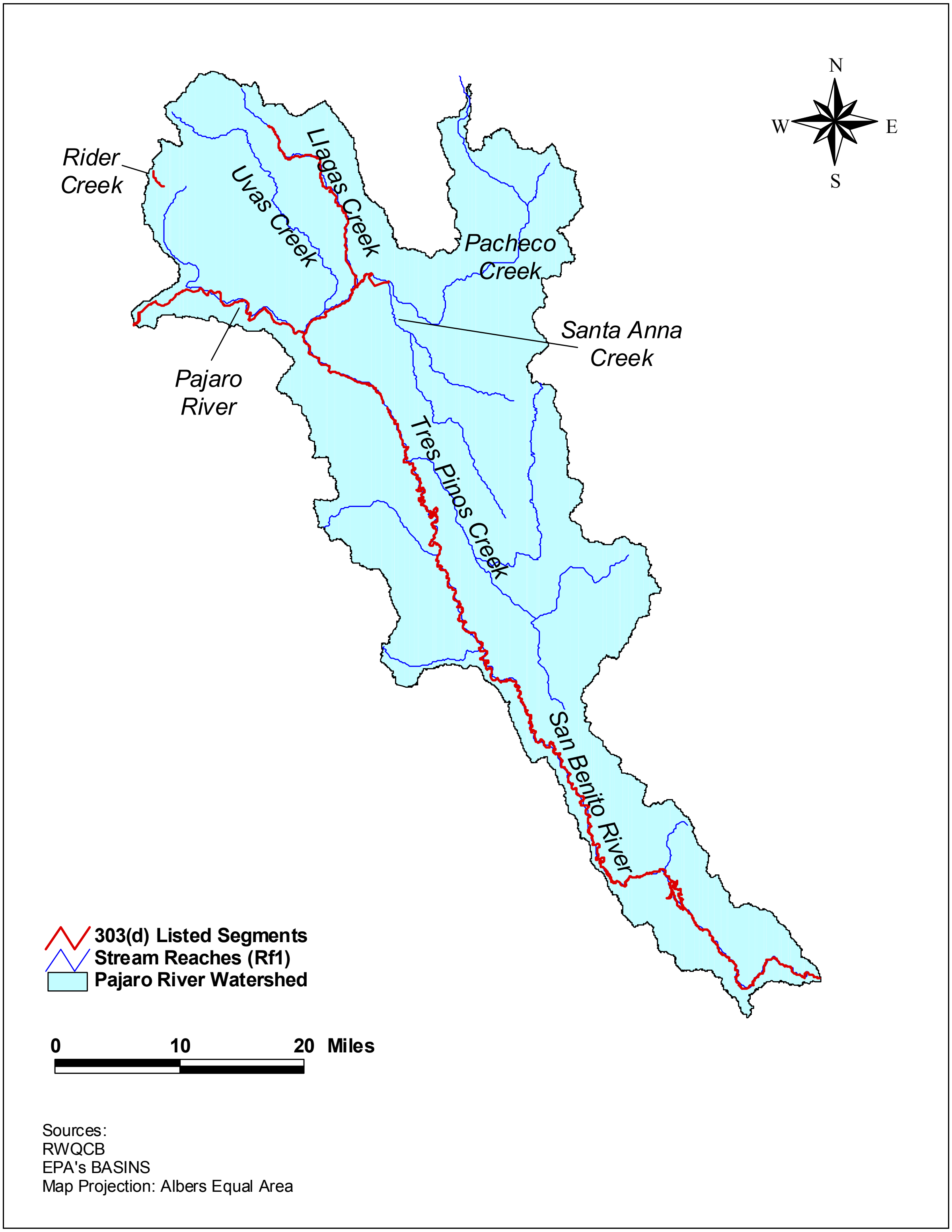



Figure 1-2. Waterbodies on 1998 Section 303(d) List, Pajaro River Watershed.

### 1.2.1 Pajaro River Sediment Impairment

The basis for including the Pajaro River on the 1998 Section 303(d) list is the report entitled *The Establishment of Nutrient Objectives, Sources, Impacts, and Best Management Practices for the Pajaro River and Llagas Creek* (San Jose State University 1994), which compiled and collected turbidity data, measured in nephelometric turbidity units (NTU), at various locations in the watershed from the early 1950s through 1993. A summary and range of values are provided for turbidity data collected from the 1950s through 1991, while individual turbidity measurements are presented for data collected from 1992 through 1993 at seven stations in the watershed. California determined that the Pajaro River should be listed as impaired by sediment on the 1998 Section 303(d) list based on a qualitative assessment of turbidity data. The report did not specify which beneficial uses are impaired as a result of sedimentation/siltation.

### 1.2.2 Llagas Creek Sediment Impairment

Four of the seven monitoring stations used during data collection activities for the San Jose State University study are on Llagas Creek. Turbidity data were collected at the four stations from June 1992 through April 1993 and were used as the basis for listing Llagas Creek as impaired by sedimentation/siltation on the 1998 Section 303(d) list.

### 1.2.3 San Benito River Sediment Impairment

Information in the *Qualitative and Quantitative Analysis of Degradation of the San Benito River* (Golder Associates 1997) was used as the basis for listing the San Benito River as impaired due to sediments. The report concludes that the river is sediment-starved due to mining operations in the area, which have caused accelerated downcutting and increased headwater incision. The result is increased channel erosion and upward migration of streams and tributaries as the river seeks to reach equilibrium. The report also notes that channelization and low-flow road crossings are contributing factors.

### 1.2.4 Rider Creek Sediment Impairment

Information in the *Rider Creek Sediment Management Plan, Santa Cruz County, California* (WRC Environmental 1991) was used to justify listing Rider Creek on the 1998 Section 303(d) list as impaired by sediment/siltation. The report documented that "sediment export for the Rider Creek … has been observed to bury portions of the Corralitos Creek [during baseflow conditions]… resulting in the loss of steelhead rearing habitat in Corralitos Creek." Sediment sources and export rates in the watershed were analyzed, and approaches to reduce sedimentation were suggested.

### 1.2.5 Watsonville Slough Sediment Impairment

The Watsonville Slough was listed as impaired by sediment/siltation on the 1998 Section 303(d) list based on historical information and monitoring results that documented significant erosion/sedimentations problems. These conditions are documented in the *Water Resources Management Plan for Watsonville Slough System* (Questa Engineering 1995). The watershed and water quality analysis and the TMDL development to address sediment impairments in Watsonville Slough are not considered in this analysis. Staff from the Central Coast RWQCB are developing a sediment TMDL for the Watsonville Slough watershed as a separate project.

# 2.0 APPLICABLE CALIFORNIA WATER QUALITY STANDARDS

## 2.1 Beneficial Uses and Water Quality Objectives

The California Porter-Cologne Water Quality Control Act establishes the responsibilities and authorities of the nine Regional Water Quality Control Boards, which are directed to "formulate and adopt water quality control plans for all areas within the region." The Water Quality Control Plan for the Central Coast Region (Basin Plan) establishes the beneficial uses for each waterbody to be protected, the water quality objectives that protect those uses, and an implementation plan that accomplishes those objectives. Table 2-1 lists the beneficial uses for 303(d)-listed streams (excepting Watsonville Slough) in the Pajaro River watershed.

Table 2-1. Beneficial uses for Section 303(d) Listed Streams in the Pajaro River Watershed

| Beneficial Use | Waterbody Name | | | |
|---|---|---|---|---|
| | Pajaro River | Llagas Creek | Rider Creek | San Benito River |
| Municipal and domestic supply | ● | ● | ● | ● |
| Agricultural supply | ● | ● | | ● |
| Industrial | ● | ● | | ● |
| Groundwater recharge | ● | ● | ● | ● |
| Water contact recreation | ● | ● | ● | ● |
| Non-contact water recreation | ● | ● | ● | ● |
| Wildlife habitat | ● | ● | ● | ● |
| Cold fresh water habitat | ● | ● | ● | |
| Warm fresh water habitat | ● | ● | | ● |
| Migration of aquatic organisms | ● | ● | ● | |
| Spawning, reproduction, and/or early development | ● | ● | ● | ● |
| Rare, threatened, or endangered species | | ● | | |
| Freshwater replenishment | ● | | | ● |
| Commercial and sport fishing | ● | ● | ● | ● |

The Basin Plan contains general objectives for all inland surface waters, enclosed bays, and estuaries. General objectives applicable to the Pajaro River watershed impairments, including suspended materials, settleable material, sediment, and turbidity, are listed in Table 2-2.

Table 2-2. Applicable General Objectives

| Parameter | General Objective |
|---|---|
| **Suspended materials** | Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses. |
| **Settleable materials** | Waters shall not contain settleable material in concentrations that result in deposition of material that causes nuisance or adversely affects beneficial uses. |
| **Sediment** | The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses. |
| **Turbidity** | Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases in turbidity attributable to controllable water quality factors shall not exceed the following limits:<br>Where natural turbidity is between 0 and 50 Jackson turbidity units (JTU), increases shall not exceed 20 percent;<br>Where natural turbidity is between 50 and 100 JTU, increases shall not exceed 10 JTU;<br>Where natural turbidity is greater than 100 JTU, increases shall not exceed 10 percent.<br>Allowable zones of dilution within which higher concentrations will be tolerated will be defined for each discharge in discharge permits. |

The general objective for turbidity is of limited use in developing TMDLs because Jackson Turbidity Units are the antiquated unit for measuring turbidity and the majority of recent turbidity data (from 1990 to the present) were measured in NTU. No known conversion between the two measures is currently available.

With the exception of the turbidity objective, no numeric water quality criteria relating to sedimentation/siltation impairments are available. Therefore, an interpretation of the sediment general objective was used to develop appropriate numeric water quality targets for use in TMDL development.

## 2.2 Habitat Areas

Figure 2-1 presents the distribution of the cold and warm water fish habitat areas in the Pajaro River watershed. Dashed streams in the southern portions of the watershed represent warm water habitat, solid blue streams represent cold water rearing habitat, and double-lined blue streams represent cold water fish habitat important for migration and spawning uses. These were determined based on a review of the beneficial uses for each stream listed in the Central Coast Region's Basin Plan (see Table 2-1) and from known fish distribution as described in the following references:

Titus, R.G., D.C. Erman, and W. Snider. 2001, September 17. Draft manuscript of History and Status of Steelhead in California Coastal Drainages South of San Francisco Bay. State of California, Department of Fish and Game.

Smith, J,J. 2002, May 22. Draft report of Steelhead Distribution and Ecology in the Upper Pajaro River System. Presented at the Pajaro River Watershed Council Special Meeting.

Smith, J.J. 1977. Doctoral dissertation on the Fishes of the Pajaro River System.

Pescadero Creek, a tributary to the San Benito River, is listed as both cold and warm water habitat in the Basin Plan. Smith indicates however, that water temperatures in the creek are probably too warm to support steelhead rearing and that any adults are probably the result of straying by hatchery-reared smolts stocked in the Pajaro River and Uvas Creek.

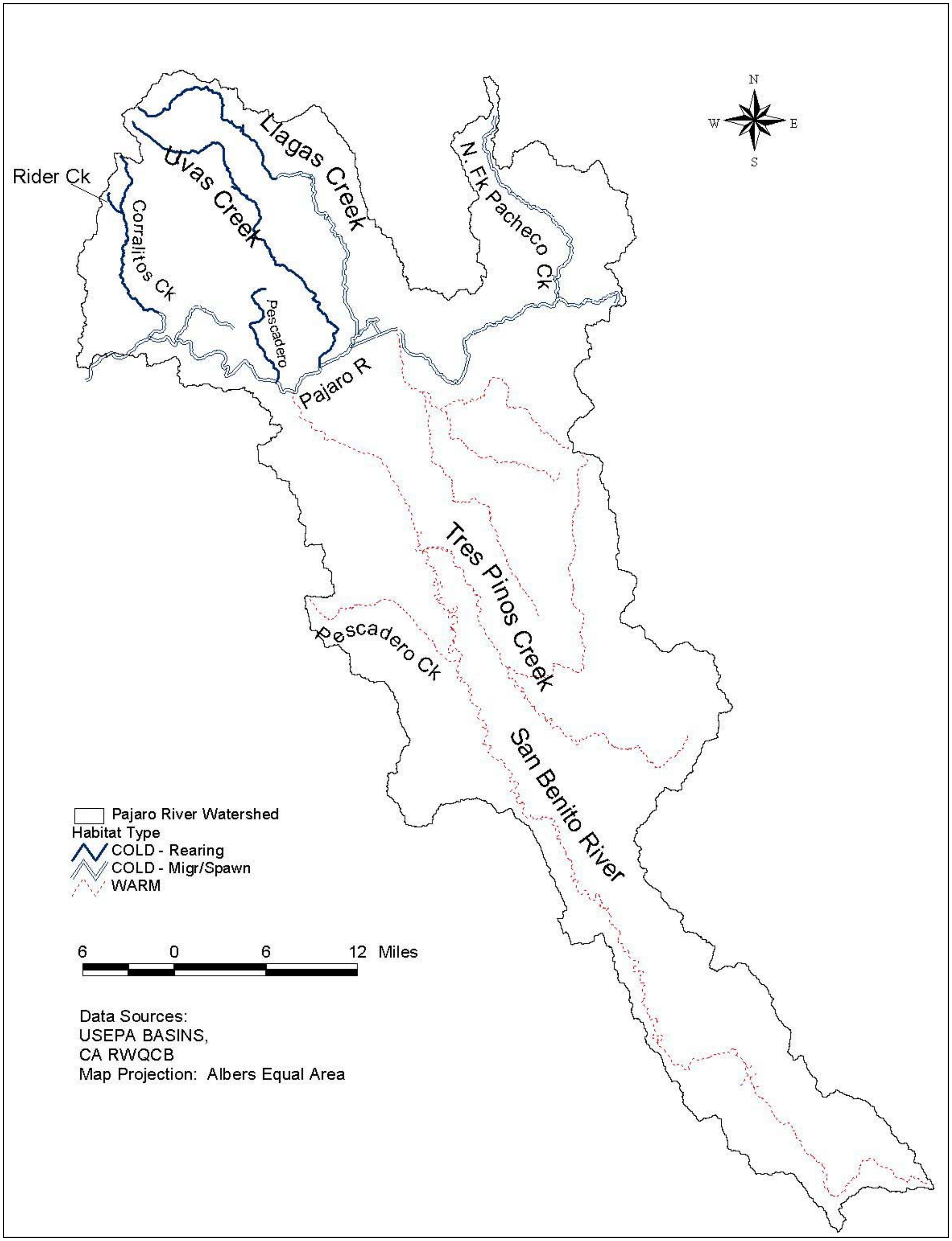



Figure 2-1. Fish habitat distribution, Pajaro River Watershed.

## 2.3 Indicator Selection

To evaluate the relationship between pollutant sources and their impact on water quality, quantitative measures (indicators) must be identified and an appropriate numeric value(s) for the indicator(s) must be selected. Together, the indicator(s) and the numeric value(s) that represent attainment with water quality objectives can be used to calculate the TMDL and measure post-implementation success. Because sediment does not have a numeric value in the RWQCB Basin Plan and the numeric objective for turbidity is not consistent with data used to identify the impairment, an indicator and a protective target value were selected for application to this TMDL.

Of the beneficial uses in the Pajaro River watershed, those related to cold and warm water habitat including spawning, migration, and rearing, will require the most stringent sediment limits.[1] The TMDL indicator and target have therefore been selected in an effort to be most protective of these uses.[2] Data on steelhead trout and local warm water fish communities (e.g., threespine stickleback, pikeminnow, prickly sculpin, sucker, California roach, speckled dace, carp, and Sacramento blackfish) in the Pajaro River watershed were assembled in an effort to identify sediment characteristics considered to be protective of those species. Because the sediment requirements of cold water species such as steelhead are more stringent than those for warm water fishes, target selection focuses on cold water species.

Critical environmental elements for sustainable steelhead fisheries include temperature, dissolved oxygen, suspended sediment concentrations, bed sediment composition, flow velocity, and depth (Barnhart 1986, Pauley et al. 1986). In reality, these elements are interrelated and together affect the ability of a stream to support a cold water fishery. For example, sediment dissolved oxygen depends on sediment texture, flow velocities, and temperature. Sediment dynamics (including suspended and bed sediments) affect a number of stages in the life history of trout. They have direct physical effects on fishes as well as indirect effects. The most important effects are on the reproductive habitat, where fine sediments fill the interstitial spaces necessary for spawning, protection, and development of eggs and fry. Sediment texture also influences cover used by fishes during juvenile stages as well as the production of invertebrate prey, the preferred food of developing trout.

Acute effects from suspended sediments usually occur at high sediment concentrations. Numerous studies have determined that prolonged high concentrations of sediment can be lethal to fish; however, the range of lethal concentrations varies widely depending on species, life cycle stage, length of duration of elevated concentration, and water temperature. Excess suspended

[1] Benthic invertebrates for example, could require even more stringent limits, but information regarding such requirements is not available at this time.

2 Steelhead trout (*Onchoryncus mykiss*) in the Pajaro River are at high risk for extinction. There has been a substantial decline in steelhead population over the past 30 years in the South-Central California Coast Region, which includes the Pajaro River. It is estimated that steelhead numbers in the Pajaro River have decreased from more than 1,000 in the 1960s to less than 100 in 1991 (NOAA 1996). Reasons for the decrease in population size include minor habitat blockages such as small dams and impassable culverts, as well as forestry practices and dewatering due to irrigation and urban water diversions.

solids contribute to reduced emergence of fry from the sediments as well, likely a function of the sedimentation associated with these suspended solids when flow recedes (Reiser and Bjornn 1979). Chronic effects of suspended solids are noticed at prolonged exposure to much lower concentrations. Turbidity during emergence of fry and juvenile development affects the number and quality of trout, and chronic exposure of 50 NTUs can reduce emergence and growth (Sigler et al. 1984).

Based on the understanding that both water column and bed sediments are known to impact fish viability, ideal indicators for the Pajaro River watershed TMDL might incorporate both bed sediment size and suspended sediment concentrations. This approach would help to ensure that the TMDL is protective of sediment impacts on fish species in the Pajaro watershed. Due to the lack of significant bed sediment data, this TMDL focuses on suspended sediment concentration (SSC) as a target for the watershed.

Streambed sediment composition is a critical component of steelhead habitat and the preservation and restoration of streams will ultimately require an understanding of streambed conditions, in addition to water column suspended solids. As a guide to post-TMDL monitoring and implementation efforts, it might be useful to use both bed sediment size and SSC to ensure that beneficial uses are supported in the future. Continued bed sediment size sampling at stations 11154700 and 11159000, as well as additional locations, can be used in follow-up studies to develop local background sediment characteristics. Ultimately, the reaches within the Pajaro watershed that support reproducing steelhead populations will provide insight into the real habitat requirements of those populations, and the literature values presented in this document should serve as suitable guidelines until sufficient local data are collected. It is also noted that if the other elements exceed the thresholds necessary for sustaining steelhead, sediment mitigation alone will not restore the fish habitat.

## 2.4 Numeric Target Selection

The magnitude and duration of sediment concentrations are among the most critical factors affecting the health of coldwater fish. Fish have been shown to respond negatively when exposed to increasing concentrations of suspended sediments with increasing duration of exposure (Newcombe and MacDonald 1991). Several investigators, in attempts to develop methodologies for predicting the effects of sediment pollution episodes on aquatic biota, have developed mathematical models relating concentration and duration of exposure to physiological fish responses (Newcombe and MacDonald 1991; Newcombe and Jensen 1996). Because these models are based on data collected from studies of water quality and fish response, they represent potentially useful tools for predicting impacts of sediment on aquatic organisms and their outputs can be applied to the TMDL development process

Expression of the Pajaro River Watershed TMDL numeric sediment target is based on the Newcombe and Jensen "Severity of Ill Effects" concentration/ duration model. The following paragraphs provide more detail regarding Newcombe and Jensen's study methodology and its application to the Pajaro River watershed TMDL. For additional description, please refer to Newcombe and Jensen, 1996.

### 2.4.1 Severity of Ill Effects Scale

The sediment concentration/duration relationship developed by Newcombe and Jensen is based on a meta-analysis of 80 published reports on fish responses to suspended sediment in streams and estuaries. These reports covered multiple species, including salmonids, non-salmonids, freshwater fish, and estuarine fish and their responses to a wide range of sediment conditions. Although the reports reviewed as part of the meta-analysis obviously differed by author, species investigated, and conditions tested, they were all similar in that they examined suspended sediment concentration and duration of exposure, as well as the qualitative response of the species in question to the tested sediment conditions. Newcombe and Jensen created a quantitative index, the "Severity of Ill Effects" scale (SEV), by which to define the qualitative fish responses to various sediment concentration-duration scenarios. The scale groups the responses into four major effect classes: nil effect, behavioral effects, sublethal effects and lethal effects. These were further categorized into a more detailed 15-point SEV scale. Table 2-3 shows the scale used to categorize qualitative response data.

With qualitative information transformed into a quantitative scale, a database linking sediment dose (concentration and exposure duration) and fish response (SEV) was created. To compare similar species, the authors also grouped the fish data based on variations of four attributes: taxonomic group, life stage, life history, and particle size of suspended sediment (Table 2-4).

Table 2-3. Severity-of-Ill Effects Scale

| **SEV** | | **Description of Effect** |
|---|---|---|
| Nil effect | 0 | No behavioral effect |
| Behavioral effects | 1 | Alarm reaction |
| | 2 | Abandonment of cover |
| | 3 | Avoidance response |
| Sublethal effects | 4 | Short-term reduction in feeding rates; short-term reduction in feeding success |
| | 5 | Minor physiological stress; increase in rate of coughing; increased respiration rate |
| | 6 | Moderate physiological stress |
| | 7 | Moderate habitat degradation; impaired homing |
| | 8 | Indications of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition |
| Lethal and paralethal effects | 9 | Reduced growth rate; delayed hatching; reduced fish density |
| | 10 | 0-20% mortality; increased predation; moderate to severe habitat degradation |
| | 11 | >20%-40% mortality |
| | 12 | >40%-60% mortality |
| | 13 | >60%-80% mortality |
| | 14 | >80%-100% mortality |

Source: Newcombe and Jensen, 1996

Table 2-4. Data groups for SEV predictability models

| Group | Description | Sample Size |
|---|---|---|
| 1 | Juvenile and adult salmonids; particle sizes 0.5 – 250 µm | 171 |
| 2 | Adult salmonids; particle sizes 0.5 – 250 µm | 63 |
| 3 | Juvenile salmonids; particle sizes 0.5 – 75 µm | 108 |
| 4 | Eggs and larvae of salmonids and non-salmonids; particle sizes 0.5 – 75 µm | 43 |
| 5 | Adult estuarine nonsalmonids; particle sizes 0.5 – 75 µm | 28 |
| 6 | Adult freshwater nonsalmonids; particle sizes 0.5 – 75 µm | 22 |

Dose/response predictive models for the six data groups were developed by regressing SEV on the duration of suspended sediment exposure and the concentration of suspended sediment. The regressions, fit to the data, produced predictive models of the form

$$z = a + b(\log_e x) + c(\log_e y)$$

*Where*

z = calculated severity of ill effect,
x = an estimate of exposure duration, and
y = concentration of the suspended sediment (mg SS/L).

The Pajaro River TMDL numeric target is expressed based on the model developed using data from Group 1[3], adult and juvenile salmonids. That group best represents the species that require the most stringent sediment conditions in the Pajaro River and reflects the reality that the system is used by fish of both stages. Figure 2-2 presents the matrix used to help visualize the dose/response model predictions.

Duration of exposure to SS ($\log_e$ hours)

Average severity of ill effects scores (calculated)

| Concentration (mg SS/L) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ($\log_e$ mg SS/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **162755** | 10 | 11 | 11 | 12 | 12 | 13 | 14 | 14 | - | - | - | **12** |
| **59874** | 9 | 10 | 10 | 11 | 12 | 12 | 13 | 13 | 14 | - | - | **11** |
| **22026** | 8 | 9 | 10 | 10 | 11 | 11 | 12 | 13 | 13 | 14 | - | **10** |
| **8103** | 8 | 8 | 9 | 10 | 10 | 11 | 11 | 12 | 13 | 13 | 14 | **9** |
| **2981** | 7 | 8 | 8 | 9 | 9 | 10 | 11 | 11 | 12 | 12 | 13 | **8** |
| **1097** | 6 | 7 | 7 | 8 | 9 | 9 | 10 | 10 | 11 | 12 | 12 | **7** |
| **403** | 5 | 6 | 7 | 7 | 8 | 9 | 9 | 10 | 10 | 11 | 12 | **6** |
| **148** | 5 | 5 | 6 | 7 | 7 | 8 | 8 | 9 | 10 | 10 | 11 | **5** |
| **55** | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | **4** |
| **20** | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 9 | **3** |
| **7** | 3 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 7 | 8 | 9 | **2** |
| **3** | 2 | 2 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 7 | 8 | **1** |
| **1** | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 7 | 7 | **0** |
| | **1** | **3** | **7** | **1** | **2** | **6** | **2** | **7** | **4** | **11** | **30** | |
| | **Hours** | | | **Days** | | | **Weeks** | | **Months** | | | |

Figure 2-2. Predicted dose/response matrix for Group 1 model.

For a given sediment dose, the matrix shows the corresponding SEV score as predicted by the regression model. For example, a suspended sediment concentration of 8,103 mg/L for a period of 2 days would be expected to produce an SEV of 10. The SEV cell values are separated by diagonal terraced lines denoting thresholds of sublethal effects (lower left) and lethal effects (middle diagonal) with reference to the four response categories listed in Table 2-3. Grey boxes surrounding SEV-8 in the 1 day to 7-week range highlight the area of focus for this study. Axes are shown in logarithmic (top and right side) and absolute (bottom and left side) terms. The concentration and duration values shown in the matrix are the median values of the range of concentrations and durations associated with a predicted SEV. The range of logarithmic values represented by a row or column is approximately the value ±0.49999 in log units. To obtain the absolute value ranges, take the antilog values of the log ranges (Table 2-5). For example, the concentration 1,097 mg/L is representative of the range from approximately 665 mg/L to approximately 1,808 mg/L.

[3] For Group 1, Juvenile and adult salmonids, intercept (a) = 1.0642, slope of $\log_e x$(b) = 0.6068, and slope of $\log_e y$(c) = 0.7384.

Table 2-5. Concentration Ranges for Predicted SEV[a]

| Absolute Value Concentration (SS mg/L) | log e Concentration (SS mg/L) | log e Concentration Range (SS mg/L) | Absolute Value Concentration Range (SS mg/L) [b] |
|---|---|---|---|
| 162755 | 12 | 11.50001 - 12.4999 | 98716.75 – 268310.45 |
| 59874 | 11 | 10.50001 - 11.4999 | 36315.86 – 98716.75 |
| 22026 | 10 | 9.50001 - 10.4999 | 13359.86 – 36315.86 |
| 8103 | 9 | 8.50001 - 9.4999 | 4914.81 – 13359.86 |
| 2981 | 8 | 7.50001 - 8.4999 | 1807.86 – 4914.81 |
| 1097 | 7 | 6.50001 - 7.4999 | 665.07 – 1807.86 |
| 403 | 6 | 5.50001 - 6.4999 | 244.69 – 665.07 |
| 148 | 5 | 4.50001 - 5.4999 | 90.01 – 244.66 |
| 55 | 4 | 3.50001 - 4.4999 | 33.11 – 90.00 |
| 20 | 3 | 2.50001 - 3.4999 | 12.18 – 33.11 |
| 7 | 2 | 1.50001 - 2.4999 | 4.48 – 12.18 |
| 3 | 1 | 0.50001 - 1.4999 | 1.64 – 4.48 |

[a] Based on Group 1 Model ; [b] Values are rounded

As expected, the dose matrix shows regular increases of response severity with increasing doses. For example, a sediment concentration between 665 and 1,808 mg/L that lasts for at least a 24-hour period (1 day) might be expected to elicit a physiological response categorized as an ‘8’ on the SEV scale, producing major physiological stress in fish. This would be classified as ranking in the sublethal range. Longer exposure durations of the same concentrations are predicted to elicit increasingly deleterious effects. Theoretically, the SEV scores within the dose/response matrix allow for estimating the minimum concentrations and durations that might be expected to trigger sublethal and lethal effects in fish and provide a potential mechanism through which a numeric sediment target can be expressed for the Pajaro River watershed sediment TMDL.

However, the data used to develop the dose/response regression model were drawn from a variety of studies of fish populations from multiple geographic areas. The model predictions described above may not be directly applicable to the Pajaro River watershed. To establish a framework applicable to the Pajaro watershed and identify Pajaro-specific thresholds, natural conditions were modeled, and the range and duration of naturally occurring sediment concentrations was identified and compared to the concentration duration ranges associated with the regression-derived SEV-8 thresholds. This comparison is the basis for expressing the target numerically. Sections 2.4.2 and 2.4.3 provide additional description regarding the selection of sediment concentration duration as the indicator and the derivation of a numeric expression for the target.

### 2.4.2 Concentration - Duration Threshold

It is assumed that suspended sediment concentration is among the critical factors limiting success of steelhead. Given its geologic setting and winter storm patterns, the Pajaro River watershed would be expected to experience high sediment concentrations under natural conditions and fish populations would also be expected to exhibit some resilience to such events. However, based on the observed lack of steelhead in the watershed, it appears that the Pajaro is currently exceeding the threshold condition at which populations are permanently suppressed. The exact threshold is not known at this point. For the Pajaro sediment TMDL, the numeric target is based on the assumption, supported by available literature, that controlling sediment concentration and duration should provide protection of the most sensitive beneficial uses. Modeling and analysis was conducted by comparing natural modeled conditions with the SEV-8 framework, which, based on the data analyzed, suggests the associated concentration – duration combinations will be protective of those uses.

Based on a limited dataset and modeled existing conditions, Pajaro River watershed sediment concentrations routinely exceed levels and durations associated with the SEV of 8. At this response level, one would expect to see indications of major physiological stress, long-term reduction in feeding rate and success, and poor condition of fish–characteristics of sublethal effects. Given that the dose/response model was developed using study data from a wide range of species and conditions, uncertainty is inherent in the model predictions. There is also a great deal of sediment concentration variability in the Pajaro River watershed even under natural conditions. Refining the regression model with data from additional steelhead-specific studies can reduce some of this uncertainty and may eventually lead to changes in the thresholds associated with SEV-8.

In the absence of more steelhead specific local data, this study makes use of a calibrated watershed model to generate a ‘natural condition’ set of concentration--duration ranges that can serve as the target for the watershed. The modeled time series were analyzed with respect to the SEV-8 framework and expressed in terms of the SEV-8 concentrations. Basing the Pajaro TMDL target on the range of concentration durations expected to occur under natural conditions should reduce the instances of chronic and lethal conditions in the watershed, while acknowledging natural variability of sediment delivery and transport in the system.

### *2.4.3 Numeric Target*

Table 2-6 shows the SEV-8 threshold combinations of sediment concentrations and duration based on the selected regression model (Group1-adult and juvenile salmonids). For discussion, this report refers to the combination of sediment concentration and duration as the sediment ‘exposure’. Exposure category refers to the combination of paired sediment concentrations and durations. The first column of Table 2-6 lists exposure categories and their related maximum concentrations as predicted from Figure 2-2. Categories A through E, outlined in bold, are the focus of this study. The sediment concentration value listed in the second column is the maximum value within the range of concentrations associated with a given exposure category. The associated range is shown in the fourth column.

The range of SEV-8 exposures can be used as an example target to illustrate how the sediment exposure concept can be applied to Pajaro sediment TMDL endpoints. For example, to meet the SEV-8 threshold, exposure category A indicates that water column sediment concentrations should not exceed 1808 mg/L for more than one day. To satisfy the threshold for exposure category B, water column sediment concentrations should not exceed 665 mg/L for more than two days. The range of concentration values associated with each exposure category is derived from the corresponding log $_e$ range (See Table 2-5).

Table 2-6. Regression Model SEV-8 Thresholds

| Exposure Category | SEV-8 Threshold Concentration (SS mg/L) | SEV-8 Threshold Duration (days) | Concentration Range (SS mg/L) | log $_e$ Concentration (SS mg/L) |
|---|---|---|---|---|
| A | 1808 | 1 | 665.14--1807.86 | 7 |
| B | 665 | 2 | 244.69--665.07 | 6 |
| C | 244 | 6 | 90.01--244.66 | 5 |
| D | 244 | 14 | 90.01--244.66 | 5 |
| E | 90 | 49 | 33.11--90.01 | 4 |
| F | 33 | 120 | 12.18--33.11 | 3 |
| G | 12 | 330 | 4.48--12.18 | 2 |

Note: Based on SEV level 8, Group 1 model.

The SEV-8 thresholds presented in Table 2-6 represent a range of ideal conditions, based on predictive models developed using laboratory-derived fish response data. The laboratory-derived data do not explicitly account for fish behavior under environmental conditions, (e.g. the ability to find short term refuge from increased sediment concentrations of an acute nature). Given the nature of sedimentation in the Pajaro River watershed, episodic extremes in sediment concentrations are expected due to storm events and loading from all sediment sources. To understand the frequency of these expected events, and to assess appropriate sediment ranges as targets with respect to fish responses in the Pajaro, it is necessary to evaluate how the system behaves under natural conditions. Unfortunately, a local reference watershed that would provide these insights is unavailable. A calibrated model, The Soil and Water Assessment Tool (SWAT), was used to derive an approximation of natural conditions by reducing anthropogenic sediment sources to the watershed (see Sections 6 and 7 for discussion of model configuration and calibration).

Modeled sediment concentrations were used to identify the expected range of sediment concentrations and durations under natural conditions. Model output (daily sediment concentration) for the natural condition simulation was compared to the SEV-8 thresholds identified in Table 2-6.[4] The numeric TMDL target—'natural condition' concentration duration—is derived from this comparison. For purposes of expressing the target, model output can be compared to any combination of exposure categories. For post-TMDL monitoring and for future comparison to refinements of the empirically derived SEV-8 thresholds, this report uses the same target exposure categories and values as those used by the SEV-8 categories. Because sediment-loading characteristics vary according to geographic location within the Pajaro watershed, discrete targets are specified for specific subwatershed areas. Figure 2-3 summarizes the numeric target development process and its linkage to overall watershed loading.

4 Default SWAT model results are output in the form of daily, monthly, or yearly loads. To evaluate SWAT sediment predictions with respect to the selected target, concentration duration, SWAT configuration files were edited to produce output as average daily concentration as well.

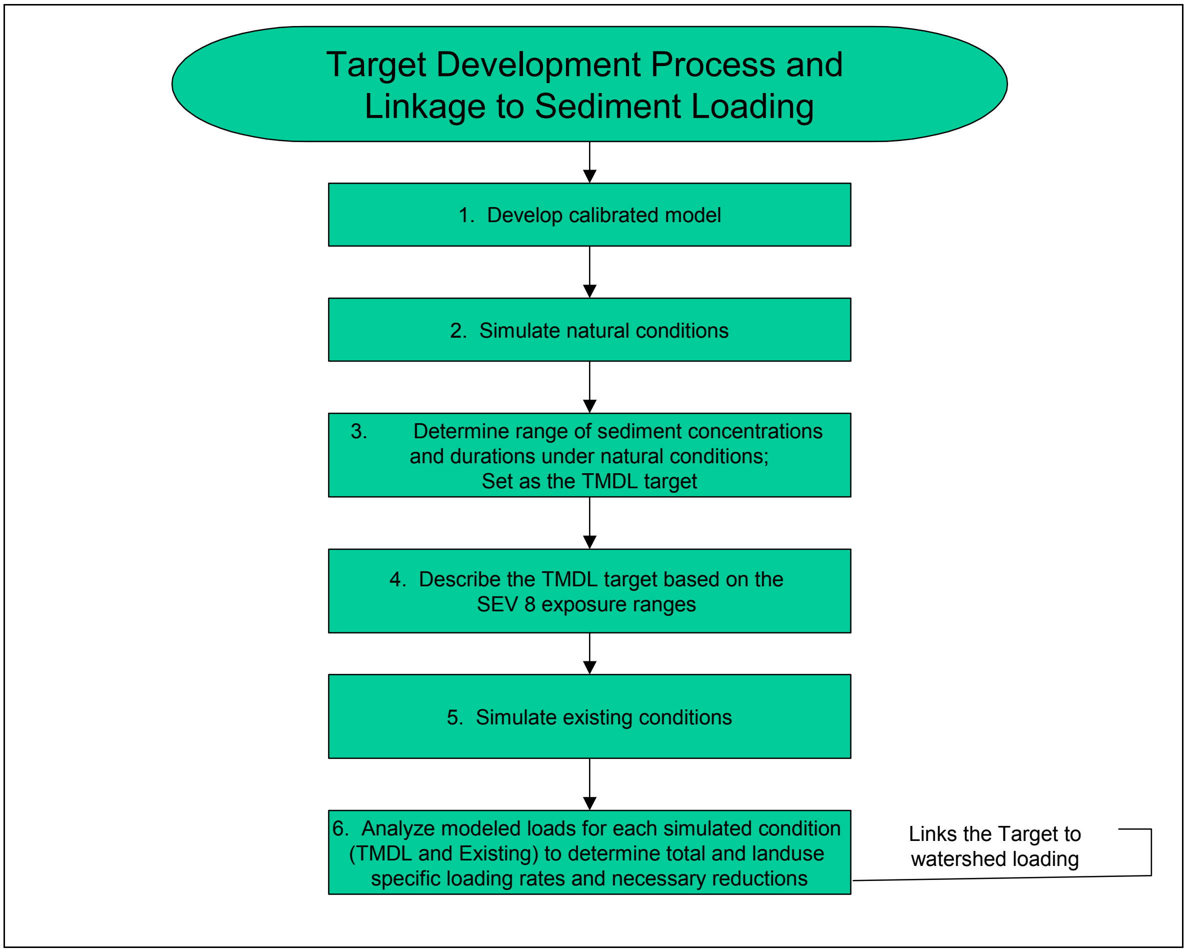



Figure 2-3. Target Development Process

A total of 7 targets were developed for the Pajaro River sediment TMDL, one for each major subwatershed. Each target encompasses a range of conditions, defined by the amount of time during which concentrations of various levels and durations are allowed to persist. Table 2-7 presents the numeric targets for the Pajaro River watershed TMDL by subwatershed. Additionally, model output for existing sediment conditions is also compared to SEV 8 categories and presented. To summarize, several categories of concentration/durations are specified as the numeric TMDL target for each major subwatershed in the Pajaro watershed. By specifying a range of categories, the numeric targets take into account the variability inherent in the system.

The numeric targets are linked to watershed loading through analysis of the total and landuse specific sediment loads for each simulated condition. Available monitoring data provide a limited picture of instream sediment values (with respect to the target) because they are based on monthly or greater sampling frequencies. The Pajaro River watershed SWAT Model allows for evaluating the selected target by providing a way to analyze sediment concentrations over continuous and extended periods of time. For post-TMDL monitoring and implementation, the targets should be used to guide the development of monitoring plans (e.g., plans should focus on daily sampling at specific locations rather than monthly).

Table 2-7. Pajaro River Watershed TMDL Targets[a]

| | | | | TMDL | | Existing | |
|---|---|---|---|---|---|---|---|
| | Exposure Category | Duration (Days) | Concentration (mg/L) | No. Periods Greater than Max Conc. | Maximum Duration (days) | No. Periods Greater than Max Conc. | Maximum Duration (days) |
| **Tres Pinos** | A | 1 | 1808 | 15 | 22 | 24 | 25 |
| | B | 2 | 665 | 42 | 44 | 46 | 45 |
| | C | 6 | 244 | 36 | 51 | 39 | 60 |
| | D | 14 | 244 | 20 | 51 | 21 | 60 |
| | E | 49 | 90 | 5 | 108 | 6 | 109 |
| **San Benito** | A | 1 | 1808 | 9 | 9 | 23 | 10 |
| | B | 2 | 665 | 30 | 21 | 39 | 28 |
| | C | 6 | 244 | 29 | 35 | 33 | 44 |
| | D | 14 | 244 | 14 | 35 | 16 | 44 |
| | E | 49 | 90 | 2 | 60 | 5 | 66 |
| **Llagas** | A | 1 | 1808 | 0 | 0 | 0 | 0 |
| | B | 2 | 665 | 0 | 1 | 8 | 8 |
| | C | 6 | 244 | 9 | 15 | 16 | 16 |
| | D | 14 | 244 | 1 | 15 | 3 | 16 |
| | E | 49 | 90 | 0 | 28 | 0 | 30 |
| **Uvas** | A | 1 | 1808 | 1 | 3 | 8 | 3 |
| | B | 2 | 665 | 12 | 8 | 20 | 8 |
| | C | 6 | 244 | 12 | 15 | 15 | 15 |
| | D | 14 | 244 | 1 | 15 | 1 | 15 |
| | E | 49 | 90 | 0 | 18 | 0 | 29 |
| **Upper Pajaro** | A | 1 | 1808 | 0 | 1 | 5 | 4 |
| | B | 2 | 665 | 3 | 3 | 21 | 8 |
| | C | 6 | 244 | 2 | 9 | 10 | 15 |
| | D | 14 | 244 | 0 | 9 | 1 | 15 |
| | E | 49 | 90 | 0 | 33 | 0 | 33 |
| **Corralitos** | A | 1 | 1808 | 0 | 1 | 1 | 2 |
| | B | 2 | 665 | 0 | 2 | 22 | 10 |
| | C | 6 | 244 | 8 | 11 | 25 | 29 |
| | D | 14 | 244 | 0 | 11 | 9 | 29 |
| | E | 49 | 90 | 0 | 36 | 1 | 60 |
| **Mouth of Pajaro** | A | 1 | 1808 | 0 | 1 | 8 | 8 |
| | B | 2 | 665 | 0 | 2 | 37 | 25 |
| | C | 6 | 244 | 8 | 11 | 26 | 75 |
| | D | 14 | 244 | 0 | 11 | 15 | 75 |
| | E | 49 | 90 | 0 | 36 | 10 | 185 |

[a] Targets based on a 15-year model run for the period from 1986 to 2000.

# 3.0 DATA INVENTORY AND ANALYSIS

Available data in the Pajaro River watershed were used to characterize the watershed and water quality conditions, identify sources, and support development of TMDLs for the watershed. No new data were collected as part of the data inventory and analysis effort.

The categories of data used in developing these TMDLs include physiographic data, primarily in GIS format, that describe the physical conditions of the watershed and environmental monitoring data that identify potential pollutant sources and their contribution. Table 3-1 presents the various data types and data sources used in the development of these TMDLs.

Table 3-1. Inventory of Data and Information used for the Source Assessment of the Pajaro River Watershed

| Data Set | Description | Source |
|---|---|---|
| **Watershed Physiographic Data** | Stream Reach Coverage | Reach File Version 1 (EPA BASINS); Reach File Version 3 (CA Central Coast RWQCB) |
| | Location information on lakes and reservoirs throughout the watershed | CA Central Coast RWQCB |
| | Soil coverage | STATSGO (EPA BASINS); CA Soils (CA Spatial Information Library) |
| | Multi-Resolution Land Characterization land use data set (1992) | CA Central Coast RWQCB |
| | Precipitation Patterns (iIsohyets of precipitation amounts based on CA weather data) | CA Spatial Information Library |
| | Weather Station Locations | CA Spatial Information Library, NCDC[a], CIMIS[b] |
| | Populated places in California | CA Spatial Information Library |
| | County coverages | CA Spatial Information Library |
| | Locations of mines | EPA BASINS; Principal Areas of Mine Pollution (PAMP) – Division of Mines and Geology; Topographically Occurring Mine Symbols (TOMS)-Office of Mine Reclamation |
| | Location of dams | EPA BASINS |
| | Digital Elevation Models (DEM) - terrain elevation | EPA BASINS, USGS |
| **Environmental Monitoring Data** | California Section 303(d) listed waterbodies | CA SWRCB |
| | Water quality monitoring data | CCAMP[c], PVWMA[d], SCRWA[e], USGS[f], SJSU[g] |
| | Streamflow data | USGS |

[a] National Climatic Data Center (NCDC).
[b] California Irrigation Management Information System (CIMIS).
[c] Central Coast Ambient Monitoring Program (CCAMP).
[d] Pajaro Valley Water Management Agency (PVWMA).
[e] South County Regional Wastewater Authority (SCRWA).
[f] United States Geological Survey (USGS).
[g] San Jose State University (SJSU).

## 3.1 Streamflow Data

Flow data are used to help determine critical conditions in the watershed and to characterize contributions from various sources.

Six active USGS gage stations in the Pajaro River watershed have data through present day. Table 3-2 presents the period of record and monthly average streamflow at the six active gages and Figure 3-1 shows their locations.

Table 3-2. Summary of active USGS gage stations

| USGS Gage ID | 11154700 | 11156500 | 11157500 | 11158600 | 11159000 | 11159200 |
|---|---|---|---|---|---|---|
| **Gage Location** | Clear Creek near Idria, CA | San Benito River near Willow Creek School, CA | Tres Pinos Creek near Tres Pinos, CA | San Benito River at Highway 156 near Hollister, CA | Pajaro River at Chittenden, CA | Corralitos Creek at Freedom, CA |
| **Period of Record** | 10/1/1993 – present day | 10/1/1939 – present day | 10/1/1940 – present day | 10/1/1970 – present day | 10/1/1939 – present day | 10/1/1956 – present day |
| **Month** | **Average Monthly Flow (cfs)** | | | | | |
| **January** | 6.74 | 33.1 | 39.3 | 72.9 | 437 | 51.30 |
| **February** | 12.6 | 72.4 | 66.2 | 174 | 649 | 62.00 |
| **March** | 15.1 | 79.4 | 40.3 | 147 | 474 | 37.80 |
| **April** | 8.60 | 43.5 | 25.4 | 42.7 | 253 | 22.00 |
| **May** | 6.30 | 22.3 | 7.08 | 16.9 | 53.6 | 5.28 |
| **June** | 4.25 | 19.9 | 5.26 | 7.65 | 16.8 | 1.13 |
| **July** | 2.19 | 14.8 | 4.82 | 5.32 | 8.25 | 0.42 |
| **August** | 1.30 | 14.4 | 4.45 | 5.11 | 6.40 | 0.19 |
| **September** | 1.02 | 11.2 | 3.62 | 4.82 | 6.53 | 0.59 |
| **October** | 1.01 | 6.58 | 2.78 | 2.91 | 5.56 | 0.81 |
| **November** | 1.02 | 5.87 | 4.17 | 6.58 | 31.9 | 5.02 |
| **December** | 1.91 | 15.4 | 15.6 | 19.4 | 144 | 16.60 |

In terms of critical flow conditions and seasonality, higher average streamflow typically occurs from November through May while lower average streamflow occurs from June through October. Based on this information and given the knowledge about sediment erosion processes, it is likely that higher sediment loadings will occur during the period from November through May.

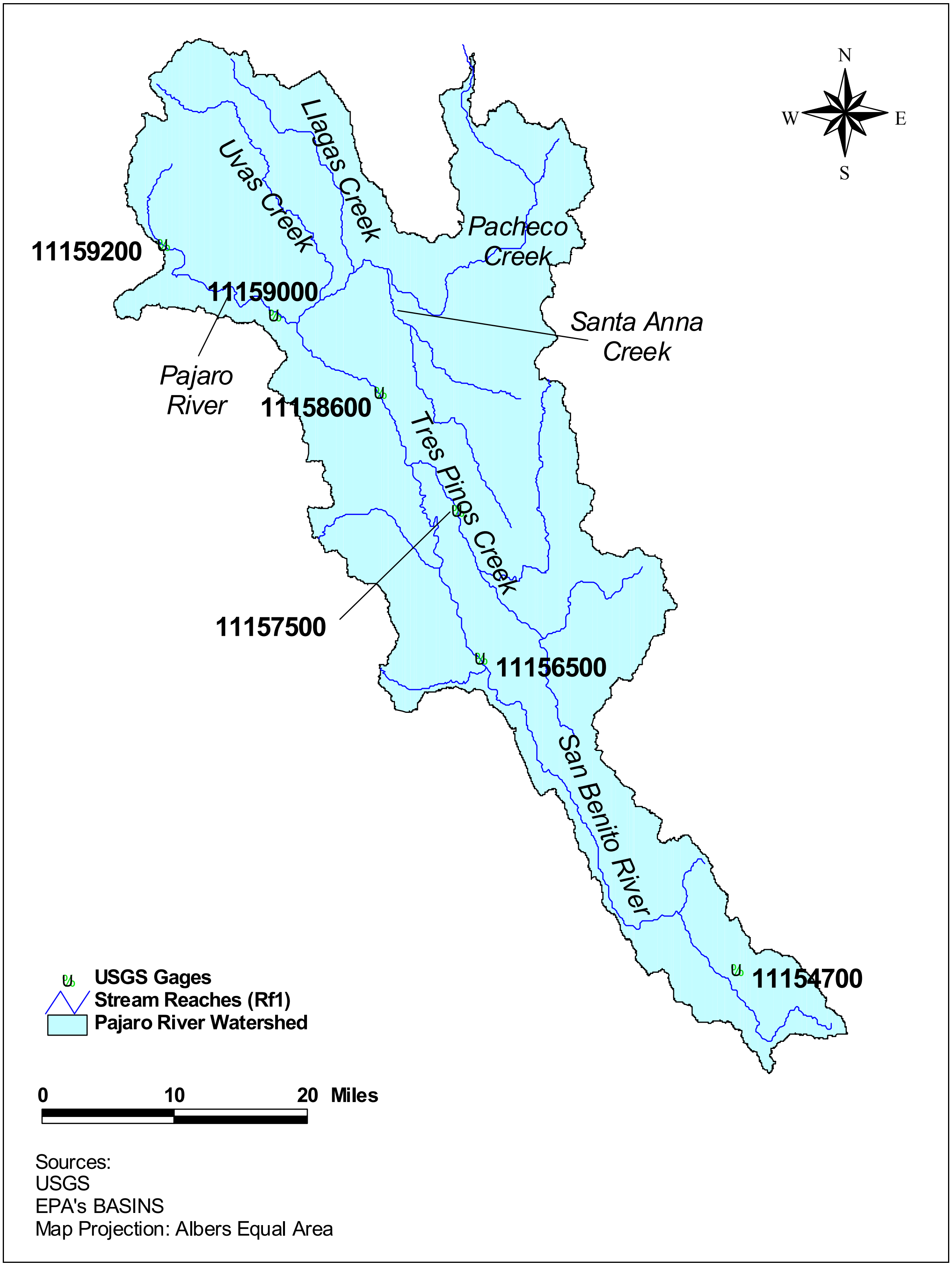



Figure 3-1. Active USGS gage stations in the Pajaro River watershed.

In addition to the flow data at the six USGS gages, instantaneous flow measurements were occasionally taken simultaneously with measurements of turbidity and/or total suspended solids at additional sites. For instance, instantaneous flow measurements are available in data sets from San Jose State University, South County Regional Wastewater Authority, and USGS. These data were used in verifying and calibrating the Pajaro River watershed SWAT model.

## 3.2 Water Quality Data

Suspended sediment and turbidity data for the Pajaro River watershed are limited. Table 3-3 lists the available sediment-related data, along the collecting agency, parameters collected, number of stations for which data were collected, and period of record.

Table 3-3. Available environmental monitoring data

| Source | Description | Number of Stations | Period of Record |
|---|---|---|---|
| United States Geological Survey (USGS) | Flow, suspended sediment concentration, suspended solids loads, bed loads, and suspended sediment and bedload sediment size classifications | 5 | 11/14/1965 - 9/5/2001 |
| Central Coast Ambient Monitoring Program (CCAMP) | Turbidity and total suspended solids data from throughout the Pajaro River watershed | 23 | 12/18/97 – 8/14/02 |
| Pajaro Valley Water Management Agency (PVWMA) | Turbidity and total suspended solids data throughout the lower Pajaro and Corralitos | 12 | 10/19/1994 - 3/23/2000 |
| South County Regional Wastewater Authority (SCRWA) | Flow and turbidity data at 4 points on the Llagas Creek near Gilroy/Morgan Hill | 4 | 3/2/1983 – 12/17/2002 |
| San Jose State University (SJSU) | Flow and turbidity data in the lower Pajaro River and Llagas creek watersheds | 6 | 6/18/1992 – 7/13/1993 |

No data are available from the Modern STORET database system (post-1998), and the Legacy STORET has limited data. Much of the data from the STORET system were collected during the 1960s through the early 1980s; an additional 26 TSS observations are available at STORET stations in the watershed from August 1994 through December 1994. Figures 3-2 through 3-5 show the locations of the United States Geological Survey (USGS), Central Coast Ambient Monitoring Program (CCAMP), Pajaro Valley Water Management Agency (PVWMA), South County Regional Wastewater Authority (SCRWA) and San Jose State University (SJSU) monitoring stations in the Pajaro River watershed.

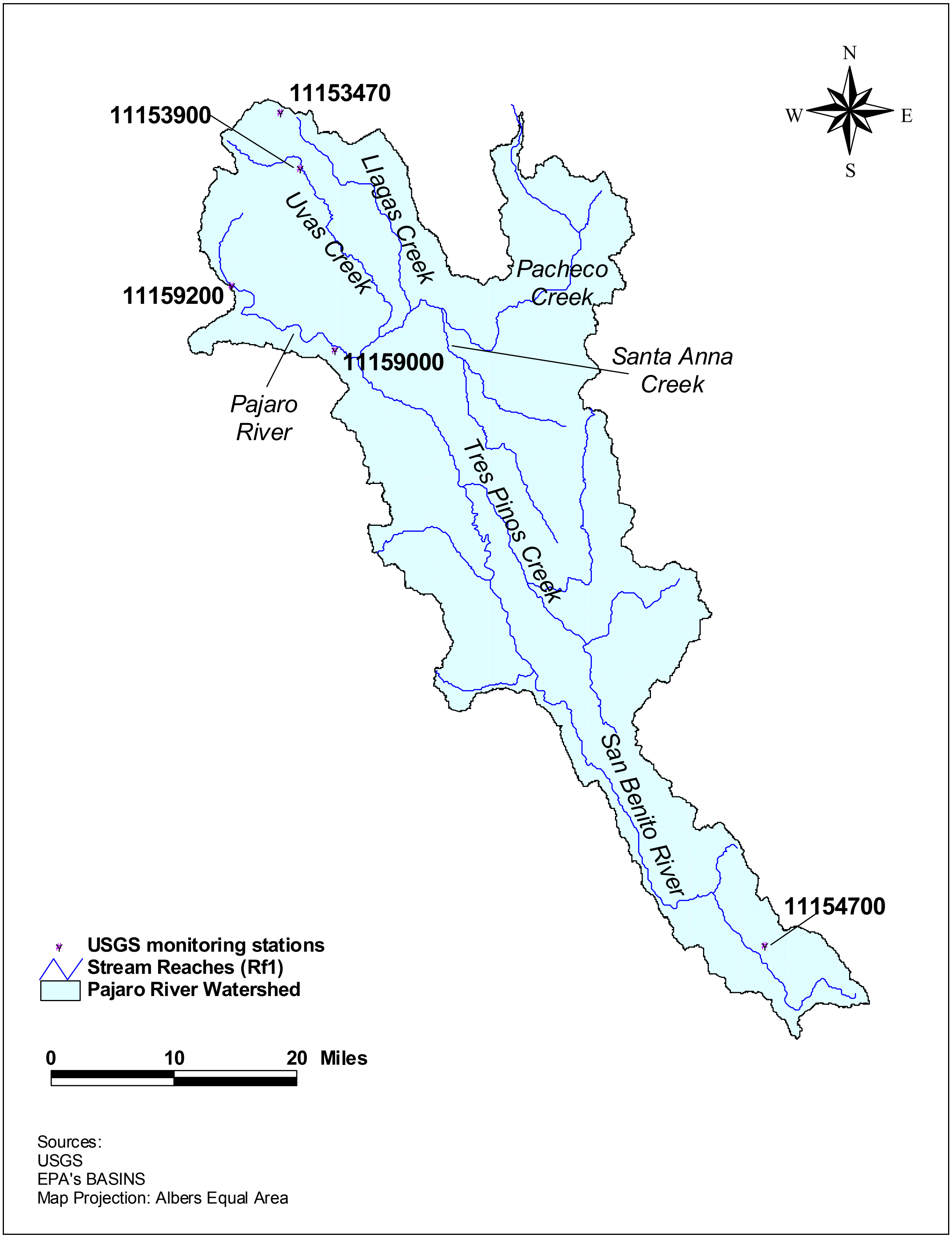



Figure 3-2. USGS sediment monitoring stations in the Pajaro River watershed.

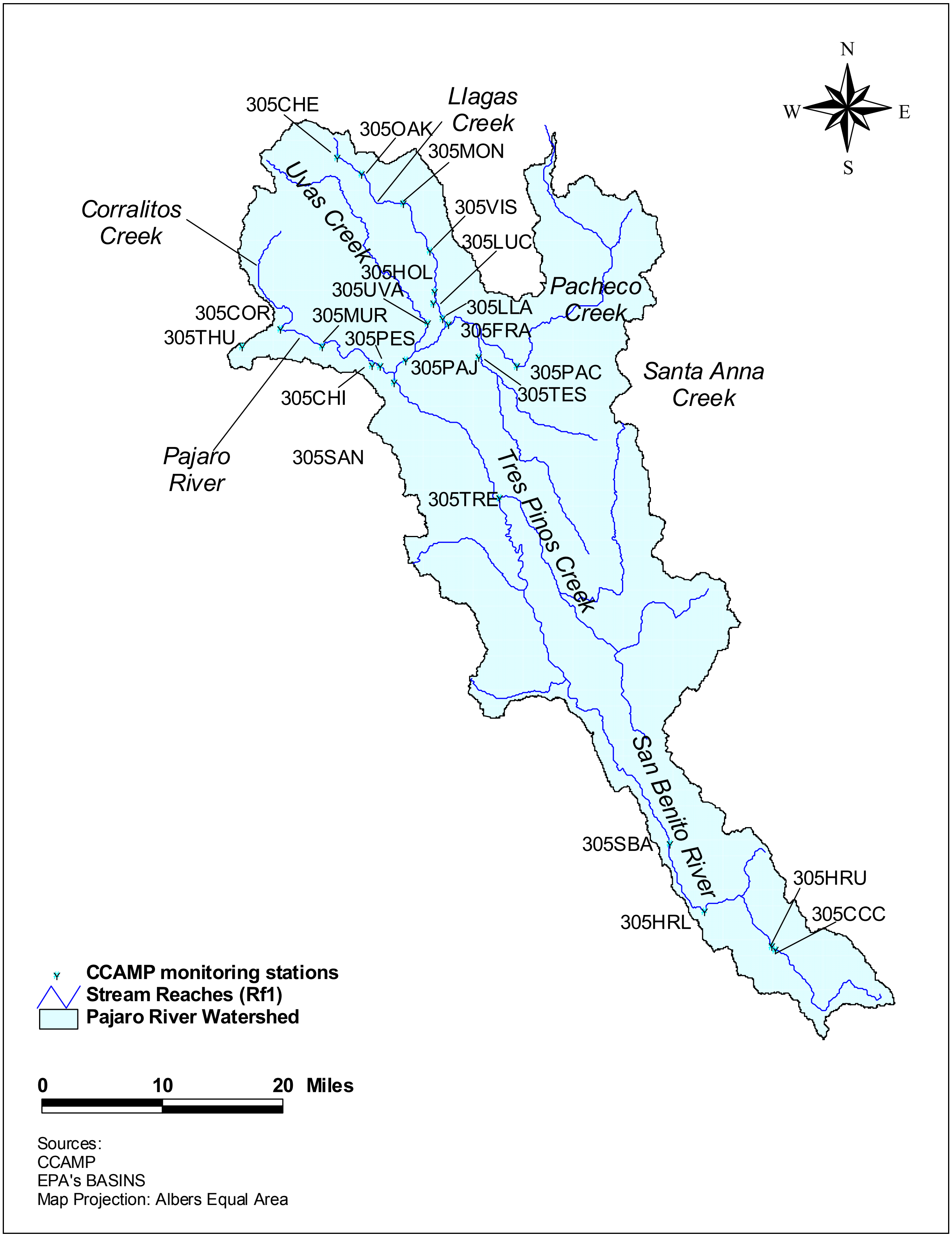



Figure 3-3. CCAMP monitoring stations in the Pajaro River watershed.

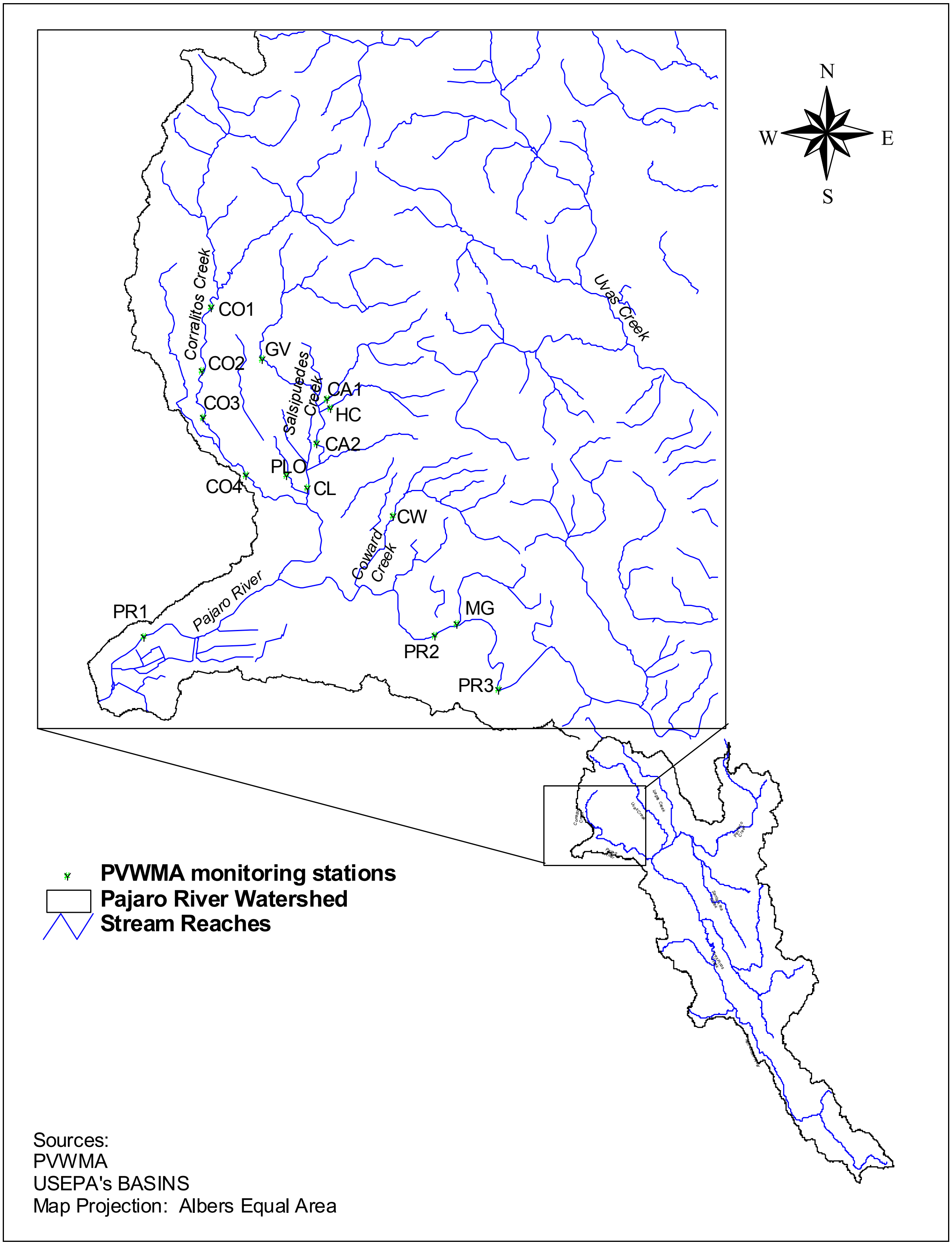



Figure 3-4. PVWMA monitoring stations in the Pajaro River watershed.

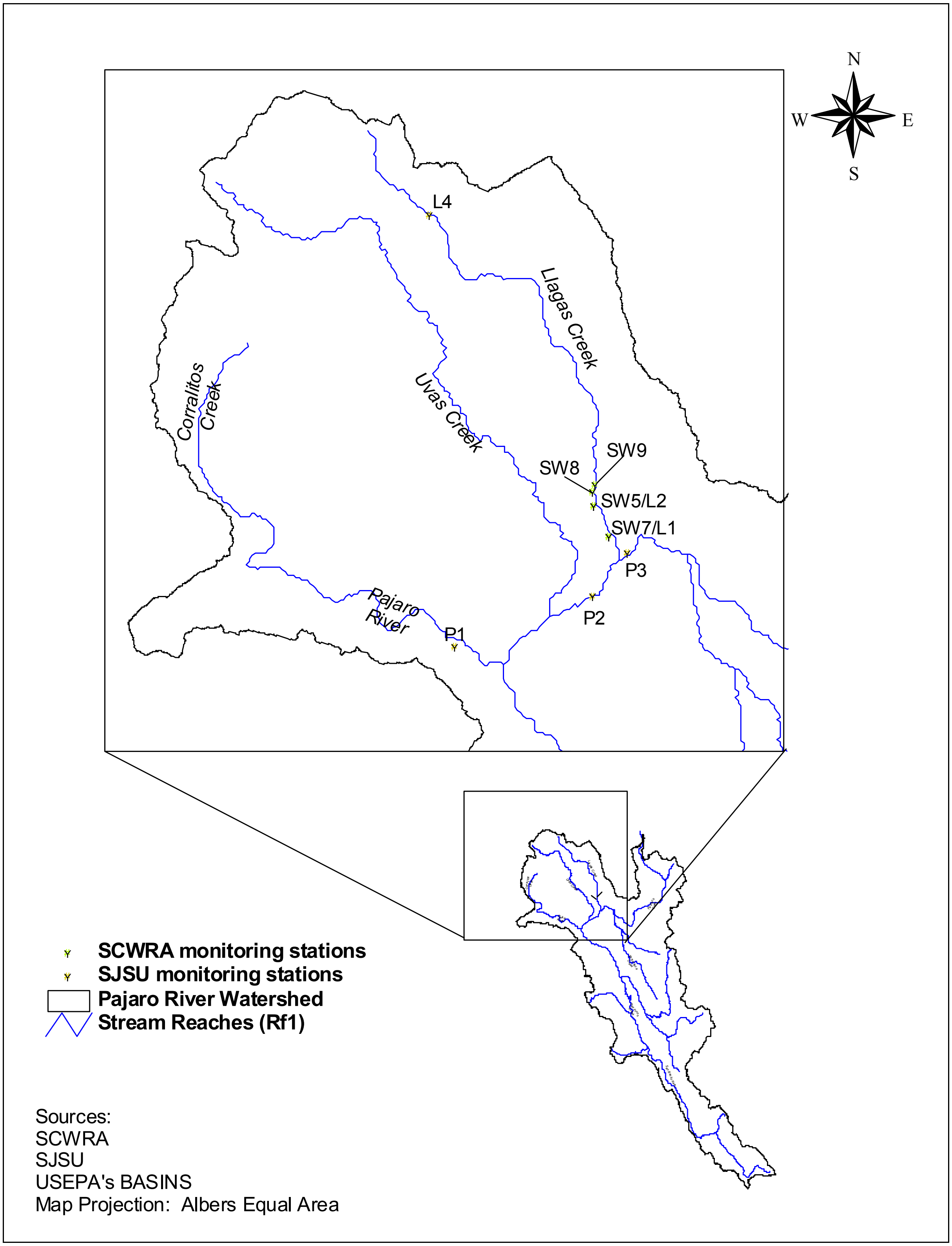



Figure 3-5. SCRWA and SJSU monitoring stations in the Pajaro River watershed.

### 3.2.1 USGS

In addition to hydrologic data, the USGS collects sediment data at selected gage stations. Table 3-4 summarizes the flow and suspended sediment concentration (SSC) data available at USGS gage stations throughout the Pajaro River watershed. Section 3.2.6 presents seasonal variations and general statistics for flow and SSC concentrations observed at three of the USGS gages (11159200, 11159000, and 11154700). These three stations were chosen for analysis because they have flow data that correspond to the SSC data and they have the most recent data (post-1980). The data analysis shows that high sediment concentrations tend to occur during high flow periods, indicating that runoff during storm events is a significant source of sediment (especially during late winter and early spring).

Table 3-4. Sediment Data Collected at USGS Gage Stations

| Station Number | Station Location | Number of Samples | Period of Record | Flow (cfs) | | | SSC (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Mean | Max | Min | Mean | Max |
| **11153470** | Llagas Creek above Chesbro Reservoir | 18 | 12/24/1971--3/5/1978 | 0 | 199.1 | 850 | 16 | 1037.4 | 4,710 |
| **11153900** | Uvas Creek above Uvas Reservoir | 48 | 11/14/1965--2/29/1976 | 0.28 | 311.2 | 1250 | 17 | 442.6 | 2,990 |
| **11154700** | Clear Creek near Idria, CA | 52 | 11/30/1993--9/5/2001 | 0.2 | 9.12 | 85 | 0 | 287 | 3,720 |
| **11159000** | Pajaro River at Chittenden, CA | 107 | 2/1/1978--9/8/1992 | 0.1 | 70.88 | 2180 | 2 | 166.4 | 2,230 |
| **11159200** | Corralitos Creek at Freedom, CA | 24 | 1/9/1976--4/29/1981 | 0.51 | 122.5 | 411 | 15 | 987.8 | 3,830 |

### 3.2.2 Central Coast Ambient Monitoring Program

The CCAMP is the Central Coast Regional Water Quality Control Board's regionally scaled water quality monitoring and assessment program. The purpose of the program is to provide scientific information to Regional Board staff and the public. Table 3-5 displays turbidity and TSS data available from the CCAMP data set.

The CCAMP data were collected throughout the watershed, with most of the data collected in the Llagas Creek area and the lower and upper Pajaro River watersheds. Figure 3-6 indicates increasing TSS concentrations from upstream to downstream areas, especially near the lower portions of the Pajaro River. The turbidity data exhibit the same spatial trend.

Table 3-5. Turbidity and TSS data from CCAMP

| Station | Period of Record | Number of Samples | Turbidity (NTU) | | | Total Suspended Solids (mg/L) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Min | Mean | Max | Min | Mean | Max |
| 305CCC | 1/1/99 – 3/1/99 | 3 | — | — | — | 2 | 106.6 | 315 |
| 305CHE | 2/10/98 – 3/1/99 | 18 | 0.1 | 7.6 | 43 | 0.3 | 4.2 | 36 |
| 305CHI | 12/18/97 – 3/1/99 | 31 | 17.5 | 493.6 | 2534 | 18 | 450.5 | 4,460 |
| 305COR | 12/18/97 – 3/1/99 | 20 | 1 | 52.8 | 200 | 0.3 | 397.9 | 6,000 |
| 305FRA | 2/10/98 – 3/1/99 | 21 | 65.8 | 192.1 | 444 | 16 | 112.4 | 296 |
| 305HOL | 2/10/98 – 3/1/99 | 18 | 1.4 | 26.4 | 143 | 0.8 | 11.9 | 84 |
| 305HRL | 1/1/99 – 3/1/99 | 3 | — | — | — | 1.6 | 15.7 | 30.4 |
| 305HRU | 1/1/99 – 3/1/99 | 3 | — | — | — | 2 | 127.3 | 378 |
| 305LLA | 12/18/97 – 3/1/99 | 33 | 7 | 35.4 | 188 | 3.7 | 19.2 | 65 |
| 305LUC | 2/10/98 – 3/1/99 | 18 | 0.1 | 14.2 | 105 | 1.3 | 10.4 | 58 |
| 305MON | 2/10/98 – 3/1/99 | 20 | 7.1 | 49.9 | 155 | 4.8 | 16.4 | 70 |
| 305MUR | 2/10/98 – 3/1/99 | 20 | 27.2 | 525.4 | 1850 | 16 | 234.1 | 1,840 |
| 305OAK | 2/10/98 – 3/1/99 | 20 | 16.5 | 52.2 | 145 | 2.5 | 14.4 | 37 |
| 305PAC | 12/18/97 – 3/1/99 | 20 | 5.8 | 47.6 | 222 | 0.3 | 55.2 | 362 |
| 305PAJ | 12/18/97 – 3/1/99 | 35 | 32.9 | 135.9 | 1161 | 25 | 107.4 | 1,400 |
| 305PES | 12/18/97 – 2/19/98 | 3 | — | — | — | 805 | 1505 | 1,985 |
| 305SAN | 12/18/97 – 3/1/99 | 19 | 5 | 552.3 | 2215 | 0.3 | 1018.5 | 8,870 |
| 305SBA | 1/1/99 – 3/1/99 | 3 | — | — | — | 1.2 | 79.1 | 234 |
| 305TES | 12/18/97 – 3/1/99 | 24 | 40.1 | 95.1 | 263 | 2.5 | 61.4 | 178 |
| 305THU | 12/18/97 – 8/14/02 | 137 | 0 | 256.2 | 3650 | 1 | 206.1 | 6,960 |
| 305TRE | 12/19/97 – 3/1/99 | 19 | 3 | 201.8 | 987 | 2.5 | 516.9 | 6,470 |
| 305UVA | 12/18/97 – 3/1/99 | 19 | 4.5 | 37.7 | 151 | 0.3 | 24.2 | 96 |
| 305VIS | 2/10/98 – 3/1/99 | 19 | 2.2 | 47.1 | 147 | 1.2 | 16.4 | 68 |

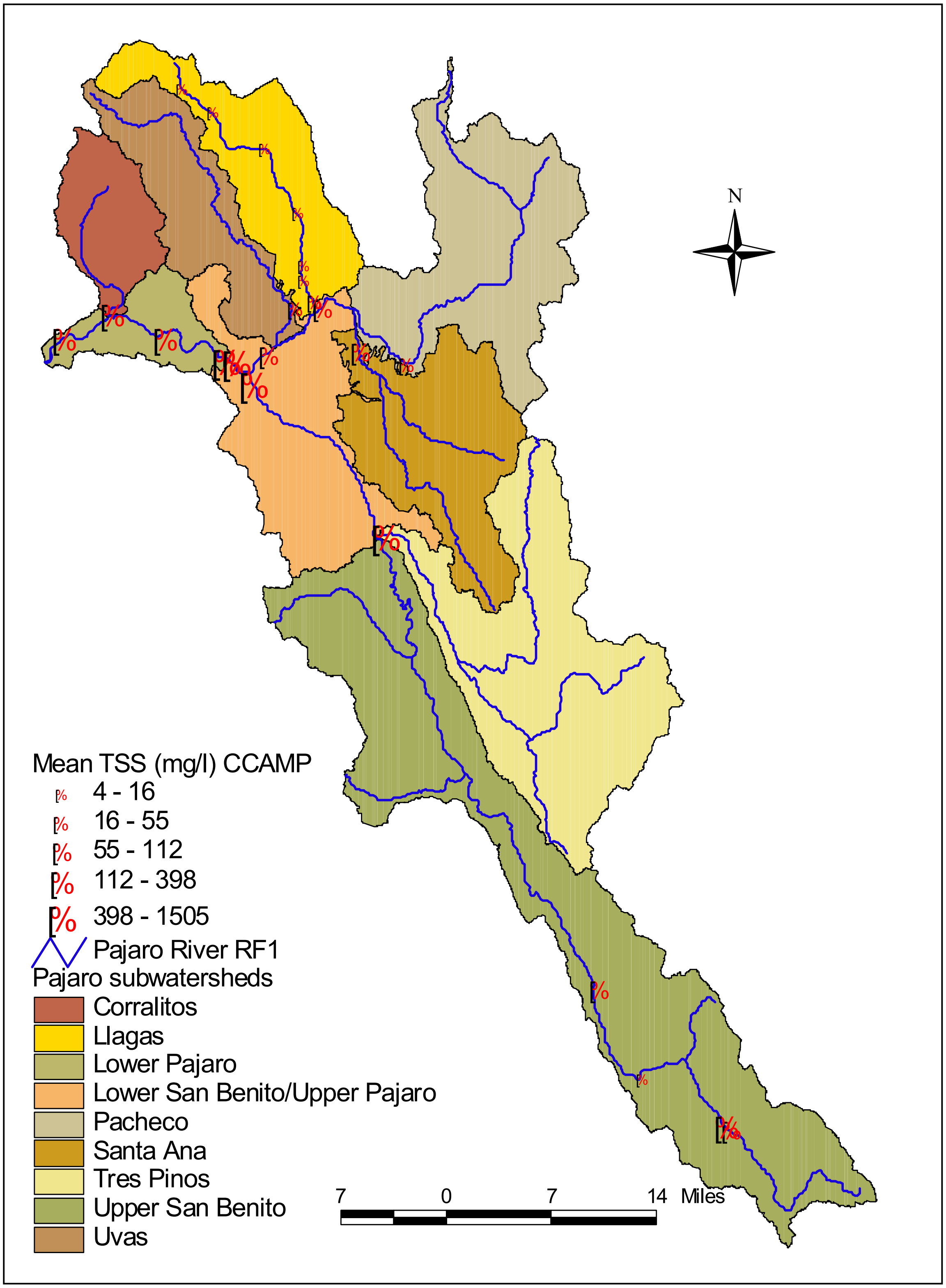



Figure 3-6. Measured mean TSS data from CCAMP.

### 3.2.3 Pajaro Valley Water Management Agency

PVWMA is a state-chartered local agency created to manage the water resources in the Pajaro River valley. The PVWMA performs water quality monitoring in various locations throughout the lower Pajaro watershed. The PVWMA data are concentrated in the Corralitos and Lower Pajaro River watersheds. Table 3-6 displays the available turbidity and TSS data collected by PVWMA.

Table 3-6. Turbidity and TSS data from PVWMA

| Station | Period of Record | Number of Samples[a] | Turbidity (NTU) | | | Total Suspended Solids (mg/l) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Min | Mean | Max | Min | Mean | Max |
| Hughes Creek (HC-1.4) | 3/18/1996 – 3/23/2000 | 7/3 | 8.4 | 34.5 | 100 | 8 | 135 | 243 |
| Coward Creek (CW-2.0) | 1/22/1995 – 3/23/2000 | 15/3 | 5 | 536.1 | 2480 | 171 | 478.7 | 887 |
| Casserly Creek (CA2-0.3) | 11/12/1994 – 3/23/2000 | 16/3 | 0.4 | 48.4 | 326 | 11 | 106.7 | 230 |
| Casserly Creek (CA1-1.7) | 3/18/1996 – 3/23/2000 | 10/2 | 0.3 | 27.2 | 87 | 117 | 132 | 147 |
| Corralitos Creek (CO4-4.2) | 1/22/1995 – 3/23/2000 | 20/3 | 0.1 | 71.1 | 790 | 4.5 | 79.8 | 169 |
| Corralitos Creek (CO3-6.0) | 3/18/1996 – 3/23/2000 | 11/3 | 0.1 | 10.1 | 44 | 1 | 46.7 | 92 |
| Corralitos Creek (CO2-7.3) | 3/18/1996 – 3/23/2000 | 10/3 | 0.1 | 9.2 | 44 | 5 | 42.7 | 92 |
| Corralitos Creek (CO1-9.8) | 11/12/1994 – 3/23/2000 | 23/3 | 0.2 | 37.1 | 490 | 3.5 | 32.2 | 61 |
| Pajaro River (PR3-2.2) | 11/12/1994 – 4/18/2000 | 25/5 | 4.2 | 116.1 | 720 | 25 | 335.8 | 1,166 |
| Pajaro River (PR2-10.9) | 1/21/1995 – 4/18/2000 | 24/1 | 5.7 | 140.2 | 980 | 44 | 44 | 44 |
| Pajaro River (PR1-14.4) | 12/8/1995 – 3/23/2000 | 21/3 | 2.8 | 109.7 | 785 | 56 | 632 | 1,536 |
| College Lake Headgate | 10/19/1994 – 2/18/1995 | 5 | 39 | 76.2 | 175 | | | |

[a]The first number listed indicates the number of turbidity samples; the second number indicates the number of TSS samples.

Both turbidity and TSS data exhibit the same trend of increasing concentrations moving from upstream to downstream. In particular, turbidity and TSS concentrations measured in the lower Pajaro River are higher than measurements at the stations on Corralitos Creek (Figure 3-7).

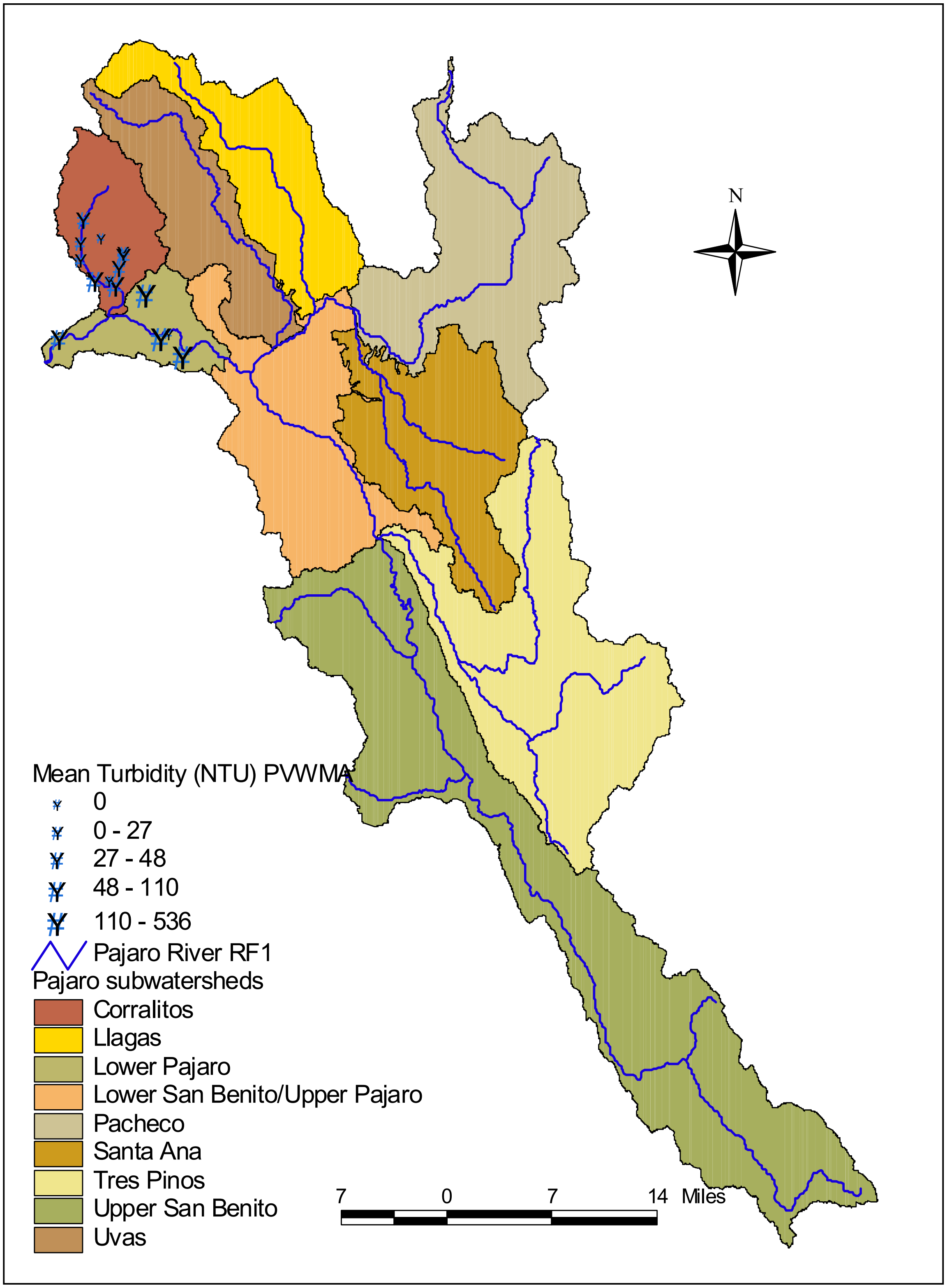



Figure 3-7. Measured mean turbidity data from PVWMA.

### 3.2.4 South County Regional Wastewater Authority

The South County Regional Wastewater Authority (SCRWA), located near the cities of Gilroy and Morgan Hill, collects water quality data on Llagas Creek near the treatment plant. The treatment plant was originally constructed in the 1920's and has been extensively expanded. Stations SW8 and SW9 are located just upstream of SCWRA, station SW5 is located in the middle of the treatment plant complex, while station SW7 is located just downstream of SCWRA. Table 3-7 presents a summary of the available SCWRA data.

Table 3-7. Turbidity Data from SCWRA

| Station ID | Number of Samples | Station Name | Period of Record | Flow (cfs) | | | Turbidity (NTU) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Mean | Max | Min | Mean | Max |
| SW5 | 40 | Llagas Creek at Luchessa Ave. Bridge | 9/12/1988--12/17/2002 | 0.0 | 19.7 | 252 | 0.95 | 6.93 | 71.1 |
| SW7 | 37 | Llagas Creek 600 ft north of Bloomfield Rd. | 9/12/1988--12/17/2002 | 0.0 | 38.5 | 640 | 2.4 | 20 | 130 |
| SW8 | 32 | Llagas Creek south of Hwy. 152 | 6/23/1992--12/17/2002 | 0.0 | 44.5 | 800 | 0.8 | 6.7 | 77.1 |
| SW9 | 17 | Llagas Creek 1,000 ft north of Hwy. 152 | 3/2/1983--12/17/2002 | 0.0 | 34 | 300 | 0.6 | 14.3 | 191 |

These stations are not shown graphically because of their close proximity to each other. Furthermore, three of the stations are colocated with San Jose State University monitoring stations. Station SW5 corresponds to station L2, station SW7 corresponds to station L1, and station SW9 corresponds to station L3.

### 3.2.5 San Jose State University

As part of the final report *The Establishment of Nutrient Objectives, Sources, Impacts, and Best Management Practices for the Pajaro River and Llagas Creek*, Merritt Smith Consulting, San Jose State University, and the cities of Gilroy and Morgan Hill conducted sampling at six locations including flow and turbidity measurements taken from 1992 through 1993. The sampling locations are concentrated near the Llagas Creek and lower Pajaro River watersheds. Table 3-8 summarizes the collected data.

Table 3-8. Turbidity Data from SJSU

| Station ID | Number of samples | Station Name | Period of Record | Flow (cfs) | | | Turbidity (NTU) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Mean | Max | Min | Mean | Max |
| L1 | 14 | Llagas Creek at Bloomfield Rd | 6/18/1992 – 7/13/1993 | 0.0 | 0.2 | 0.8 | 2.4 | 21.4 | 120 |
| L2 | 14 | Llagas Creek at Luchessa Rd. | 6/18/1992 – 7/13/1993 | 0.0 | 2.8 | 8.2 | 1.0 | 5.7 | 48 |
| L4 | 17 | Llagas Creek at California St. (USGS gage 11153500) | 6/18/1992 – 7/13/1993 | 6.2 | 13.7 | 24.2 | 3.5 | 11.5 | 52 |
| P1 | 17 | Pajaro River at Chittenden, CA (USGS gage 11159000) | 6/18/1992 – 7/13/1993 | 0.0 | 18.6 | 98.4 | 0.4 | 18.2 | 240 |
| P2 | 17 | Pajaro River at Hwy. 25 | 6/18/1992 – 7/13/1993 | 0.0 | 6.2 | 88.0 | 4.7 | 46.4 | 200 |
| P3 | 12 | Pajaro River on Frazier Lake Road | 6/18/1992 – 7/13/1993 | 0.0 | 0.0 | 0.1 | 9.9 | 47.7 | 96 |

Figure 3-8 shows the location of the six stations from the SJSU study. The turbidity data show an increasing trend of mean turbidity from upstream to downstream. This trend is particularly evident at the confluence of Llagas Creek with the Pajaro River.

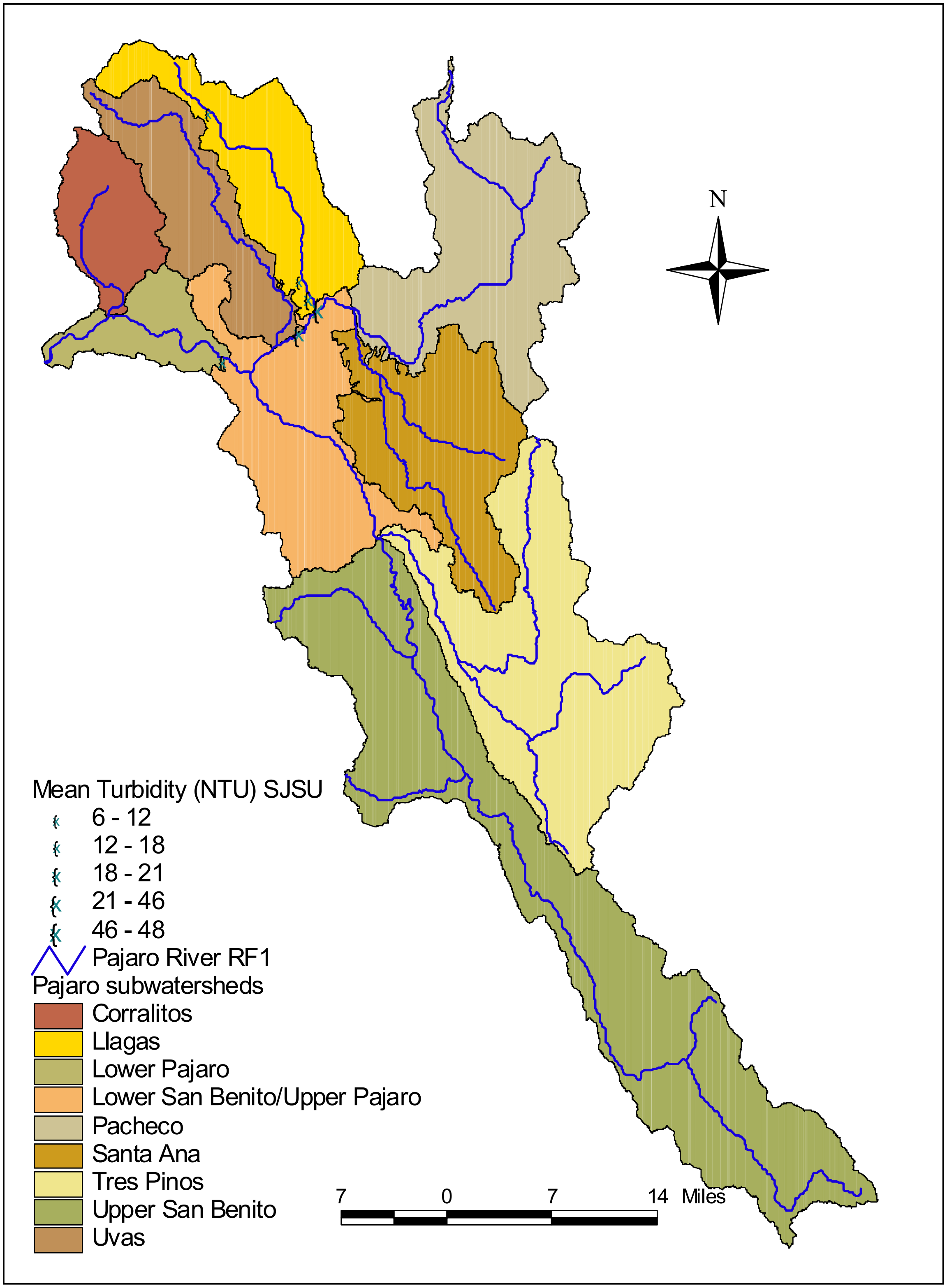



Figure 3-8. Measured mean turbidity data from SJSU.

### 3.2.6 Sediment/Flow Analysis

Because elevated sediment concentrations tend to be positively correlated with increased flow volumes, an analysis of paired sediment/flow observations was also conducted. This information is available for the Pajaro for the USGS gage stations at Clear Creek, at Corralitos Creek, and on the Pajaro River at Chittenden.

For each location, two plots were generated using flow and suspended sediment concentration observations. The first presents a monthly analysis of water quality observations and reflects seasonal patterns. Observations are grouped according to the month in which they were collected. Corresponding flow values are averaged and plotted with the monthly mean concentration. For point source-dominated loading situations, the patterns exhibited by concentration and flow graphs will tend to be opposite from one another (low flows with high concentrations). For situations in which loading is more runoff-driven, the concentration and flow patterns mirror each other. Data for the examined locations show that maximum flows usually occur in the winter months, particularly February and March. In general, December through March is the high-flow season.

The second graph for each water quality station examines the potential relationship between sediment concentrations and flow levels by presenting the flow-weighted average sediment concentrations. Available water quality observation data are paired with USGS hydrograph flow estimates for the same date. Flow values are ranked from highest to lowest and divided into percentiles. For each percentile range, average flow is shown in blue, as well as the minimum and maximum range for that percentile. Concentration data are presented in bar graph format for each percentile range. The data table above the graph provides additional summary statistics for flows and concentrations. The mean concentration listed in the data table represents the flow-weighted average concentration. For example, for the flows and concentrations in the 0 to 10 percentile range, loads are calculated and summed, flows are summed, and the total load is divided by the total flow to derive the flow-weighted average concentration. In cases where low-flow impairments are dominant, the graph would show an inverse relationship between the flow percentiles and corresponding concentrations (i.e., as flows increase, concentrations would decrease.) For a high-flow problem condition, the graph would show increasing concentrations with increasing flows. As would be expected, this is generally the case for each of the three stations examined.

Figure 3-9 presents a monthly analysis for Clear Creek and shows that for the period for which data are available, sediment is delivered primarily during the winter months of January, February, and March. Figure 3-10 illustrates flow-weighted sediment concentrations at Clear Creek. The highest sediment concentrations are associated with the top percentile flows in this watershed, indicating that the biggest sediment loads are delivered with the highest flow events.

Figures 3-11 through 3-14 present the same information for Corralitos Creek and the Pajaro River at Chittenden. Paired sediment/flow data are more limited for Corralitos Creek—there is only one observation for the month of February. Flow-weighted average sediment concentrations in Corralitos Creek tend to be higher than those at the other two stations; this might be a function of a more limited data set. The same patterns as those seen in Clear Creek are also clearly evident in the Chittenden data. Again, the highest sediment concentrations occur in conjunction with the highest percentile flow events; most sediment loading occurs during February and March.

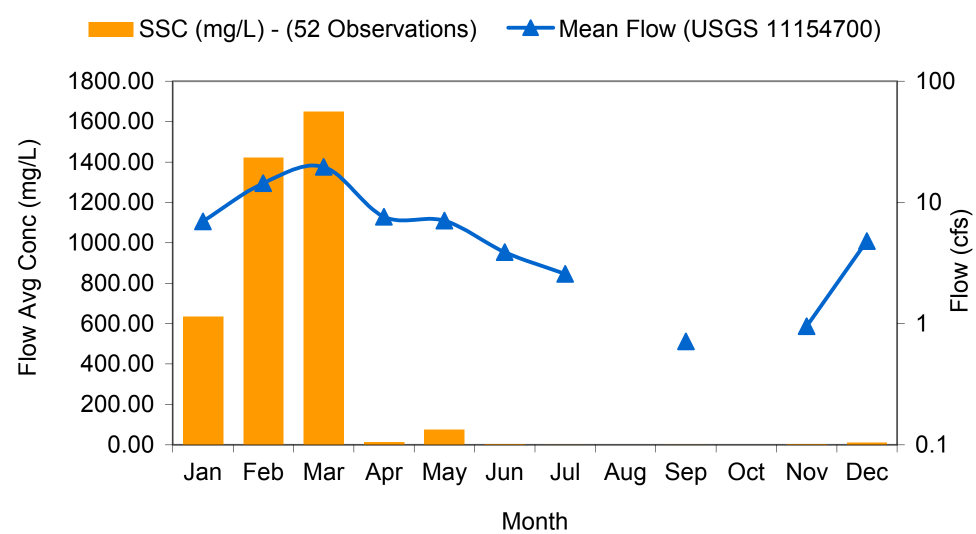



Figure 3-9. Monthly mean flow and sediment concentration, Clear Creek.

Location: Clear Creek nr Idria
Pollutant: SSC (mg/L)
Data from: 11/30/1993 to 9/5/2001 (52 Observations)

| Flow Range | # Obs | Flow (cfs) | | | Concentration (mg/L) | | |
|---|---|---|---|---|---|---|---|
| *Percentile* | *Count* | *Mean* | *Min* | *Max* | *Mean* | *Min* | *Max* |
| 0-10 | 6 | 0.537 | 0.200 | 0.980 | 1.98 | 0.00 | 6.00 |
| 10-20 | 5 | 1.220 | 1.000 | 1.400 | 5.13 | 2.00 | 8.00 |
| 20-30 | 5 | 1.780 | 1.500 | 2.200 | 8.89 | 1.00 | 30.00 |
| 30-40 | 5 | 2.520 | 2.200 | 3.000 | 12.34 | 2.00 | 38.00 |
| 40-50 | 5 | 3.640 | 3.200 | 4.100 | 22.32 | 2.00 | 72.00 |
| 50-60 | 5 | 5.360 | 4.900 | 5.900 | 6.62 | 1.00 | 22.00 |
| 60-70 | 5 | 7.360 | 6.000 | 8.400 | 446.05 | 6.00 | 1640.00 |
| 70-80 | 5 | 9.800 | 9.000 | 12.000 | 133.61 | 4.00 | 317.00 |
| 80-90 | 6 | 17.500 | 15.000 | 20.000 | 352.10 | 12.00 | 1190.00 |
| 90-100 | 5 | 44.000 | 22.000 | 85.000 | 2119.29 | 337.00 | 3720.00 |

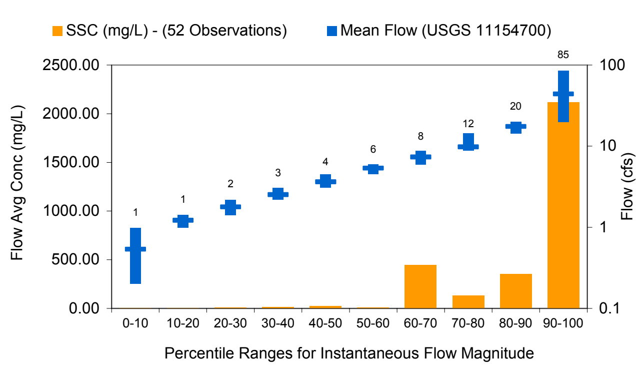



Figure 3-10. Flow-weighted average sediment concentration, Clear Creek.

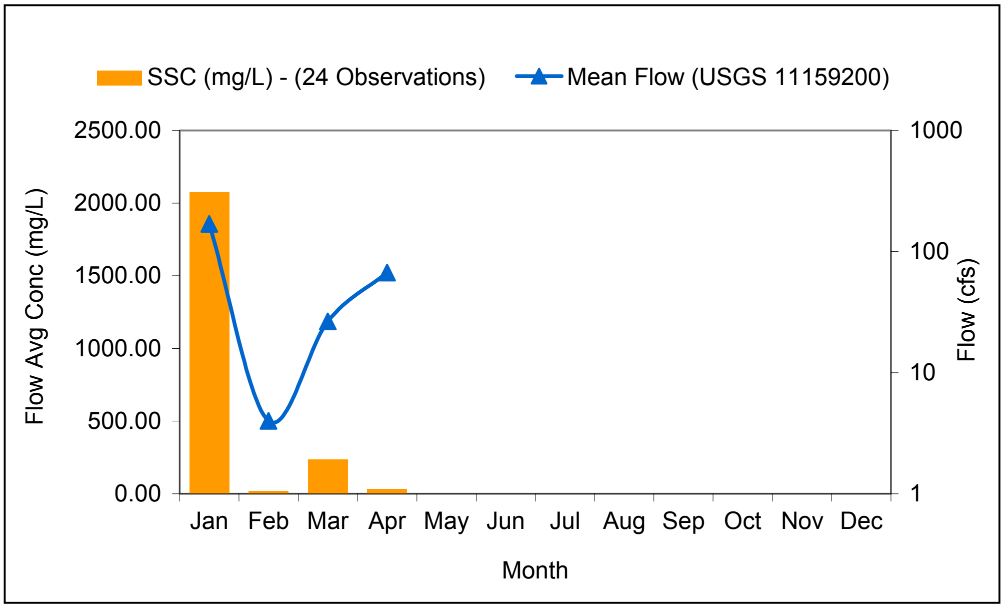



Figure 3-11. Monthly mean flow and sediment concentration, Corralitos Creek.

Location: Corralitos Creek
Pollutant: SSC (mg/L)
Data from: 1/9/1976 to 4/29/1981 (24 Observations)

| Flow Range | # Obs | Flow (cfs) | | | Concentration (mg/L) | | |
|---|---|---|---|---|---|---|---|
| *Percentile* | *Count* | *Mean* | *Min* | *Max* | *Mean* | *Min* | *Max* |
| 0-10 | 3 | 2.603 | 0.510 | 4.000 | 35.02 | 20.00 | 52.00 |
| 10-20 | 2 | 9.050 | 7.100 | 11.000 | 52.31 | 28.00 | 68.00 |
| 20-30 | 2 | 21.500 | 12.000 | 31.000 | 547.77 | 15.00 | 754.00 |
| 30-40 | 3 | 37.333 | 32.000 | 40.000 | 864.00 | 778.00 | 949.00 |
| 40-50 | 2 | 63.000 | 62.000 | 64.000 | 288.89 | 232.00 | 344.00 |
| 50-60 | 2 | 68.500 | 67.000 | 70.000 | 98.89 | 34.00 | 161.00 |
| 60-70 | 3 | 112.667 | 81.000 | 153.000 | 1311.00 | 518.00 | 1680.00 |
| 70-80 | 2 | 226.500 | 219.000 | 234.000 | 1782.78 | 1540.00 | 2010.00 |
| 80-90 | 2 | 307.500 | 301.000 | 314.000 | 1608.73 | 1550.00 | 1670.00 |
| 90-100 | 3 | 363.667 | 330.000 | 411.000 | 2976.19 | 1650.00 | 3830.00 |

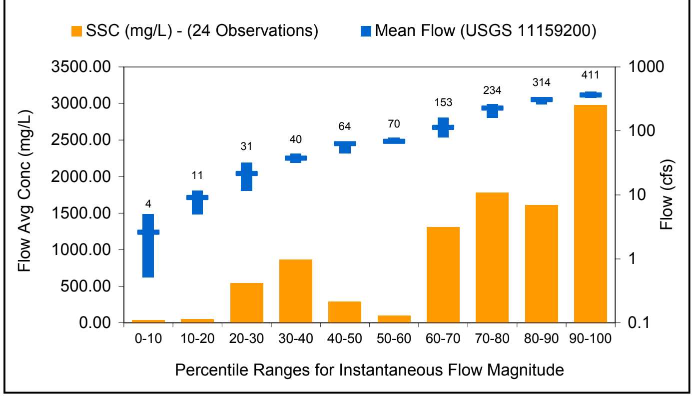



Figure 3-12. Flow-weighted average sediment concentration, Corralitos Creek.

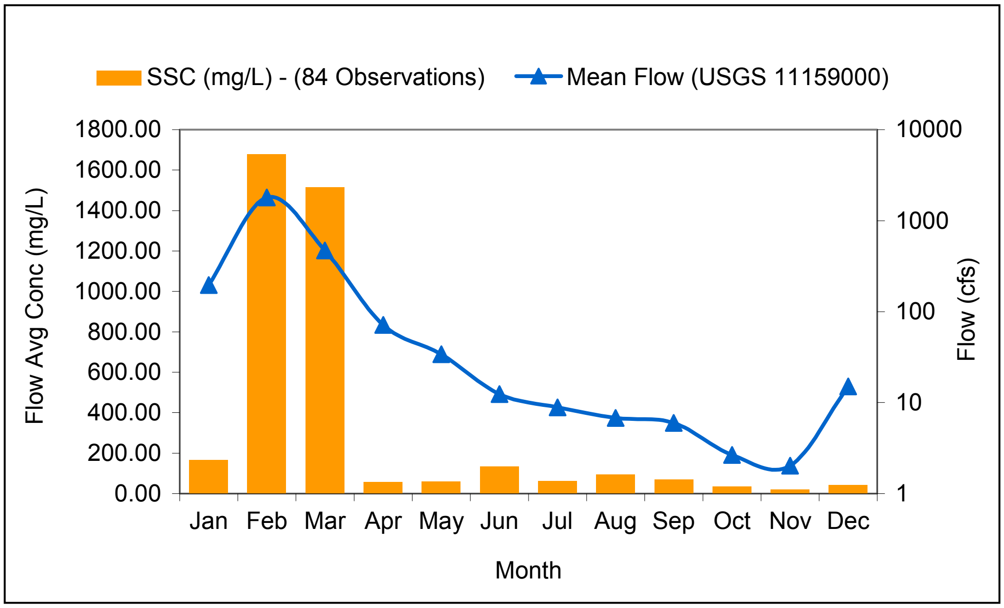



Figure 3-13. Monthly mean flow and sediment concentration, Pajaro River at Chittenden.

Location: Pajaro River at Chittenden
Pollutant: SSC (mg/L)
Data from: 2/1/1978 to 9/8/1992 (84 Observations)

| **Flow Range** | **# Obs** | **Flow (cfs)** | | | **Concentration (mg/L)** | | |
|---|---|---|---|---|---|---|---|
| *Percentile* | *Count* | *Mean* | *Min* | *Max* | *Mean* | *Min* | *Max* |
| 0-10 | 9 | 0.804 | 0.300 | 1.700 | 23.99 | 4.00 | 59.00 |
| 10-20 | 8 | 2.775 | 1.700 | 3.500 | 21.86 | 2.00 | 55.00 |
| 20-30 | 8 | 4.113 | 3.700 | 4.500 | 37.96 | 10.00 | 92.00 |
| 30-40 | 9 | 5.644 | 4.800 | 7.500 | 21.21 | 3.00 | 36.00 |
| 40-50 | 10 | 10.110 | 7.500 | 12.000 | 70.77 | 15.00 | 129.00 |
| 50-60 | 6 | 13.000 | 12.000 | 14.000 | 66.87 | 12.00 | 169.00 |
| 60-70 | 9 | 18.556 | 14.000 | 25.000 | 74.15 | 23.00 | 135.00 |
| 70-80 | 8 | 42.750 | 34.000 | 57.000 | 85.99 | 10.00 | 279.00 |
| 80-90 | 8 | 82.625 | 65.000 | 114.000 | 53.44 | 17.00 | 115.00 |
| 90-100 | 9 | 2151.667 | 126.000 | 12400.000 | 1614.48 | 30.00 | 2230.00 |

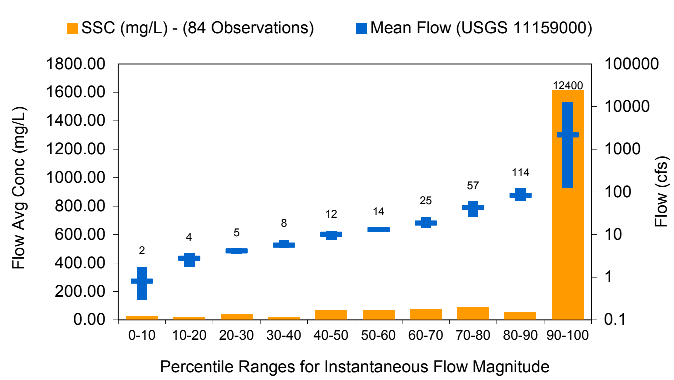



Figure 3-14. Flow-weighted average sediment concentration, Pajaro River at Chittenden.

## 3.3 Land use/Land Cover

The land uses in the Pajaro River watershed have the potential to contribute nonpoint source loads of sediment to receiving waterbodies. The land uses, along with available water quality data, were used to determine significant sources of sediment to the watershed. (Section 5 discusses the possible sources of sediment to the Pajaro River watershed in more detail.) Land uses in the Pajaro River watershed were determined using the Multi-Resolution Land Characteristics (MRLC) data set acquired from the Central Coast RWQCB. The MRLC is a consortium of federal government agencies acting together to acquire satellite imagery for various environmental monitoring programs. One program that resulted from the MRLC effort is the National Land Cover Data (NLCD) program, which used images acquired from LANDSAT's Thematic Mapper sensor, as well as ancillary data sources, to produce a national land cover data set. Table 3-9 presents the distribution of land uses in the watershed. Figure 3-15 shows the MRLC land use coverage for the Pajaro River watershed.

Table 3-9. Land Uses in the Pajaro River Watershed

| Land Use | Acres | Square Miles | Percent of Total |
|---|---|---|---|
| **Open water** | 800.6 | 1.25 | < 1% |
| **Perennial ice/snow** | 0.4 | 0.00 | < 1% |
| **Low intensity residential** | 11,402.7 | 17.82 | 1.41% |
| **High intensity residential** | 1,150.4 | 1.79 | < 1% |
| **Commercial/industrial/transportation** | 4,542.4 | 7.10 | < 1% |
| **Bare rock/sand/clay** | 12,608.4 | 19.70 | 1.56% |
| **Quarries/strip mines/gravel** | 332.4 | 0.52 | < 1% |
| **Deciduous forest** | 29,843.2 | 46.64 | 3.69% |
| **Evergreen forest** | 103,339.3 | 161.51 | 12.79% |
| **Mixed forest** | 60,832.1 | 95.08 | 7.52% |
| **Shrubland** | 134,515.8 | 210.24 | 16.64% |
| **Orchards/vineyards/other*** | 30,809.3 | 48.15 | 3.81% |
| **Grasslands/herbaceous** | 326,047.5 | 509.61 | 40.35% |
| **Pasture/hay*** | 59,600.7 | 93.15 | 7.37% |
| **Row crops*** | 29,624.5 | 46.30 | 3.66% |
| **Small grains*** | 384.4 | 0.60 | < 1% |
| **Fallow*** | 844.6 | 1.32 | < 1% |
| **Urban/recreational grasses** | 1,207.9 | 1.88 | < 1% |
| **Woody wetlands** | 15.1 | 0.02 | < 1% |
| **Emergent herbaceous wetlands** | 38.2 | 0.06 | < 1% |
| **Total** | **807,940.9** | **1,262.8** | **100%** |

* Denotes agricultural landuse types

Agricultural lands constitute about 15 percent of the Pajaro River watershed; forested lands, almost 24 percent; and grassland/shrublands/grasses, the majority of the watershed at approximately 57 percent.

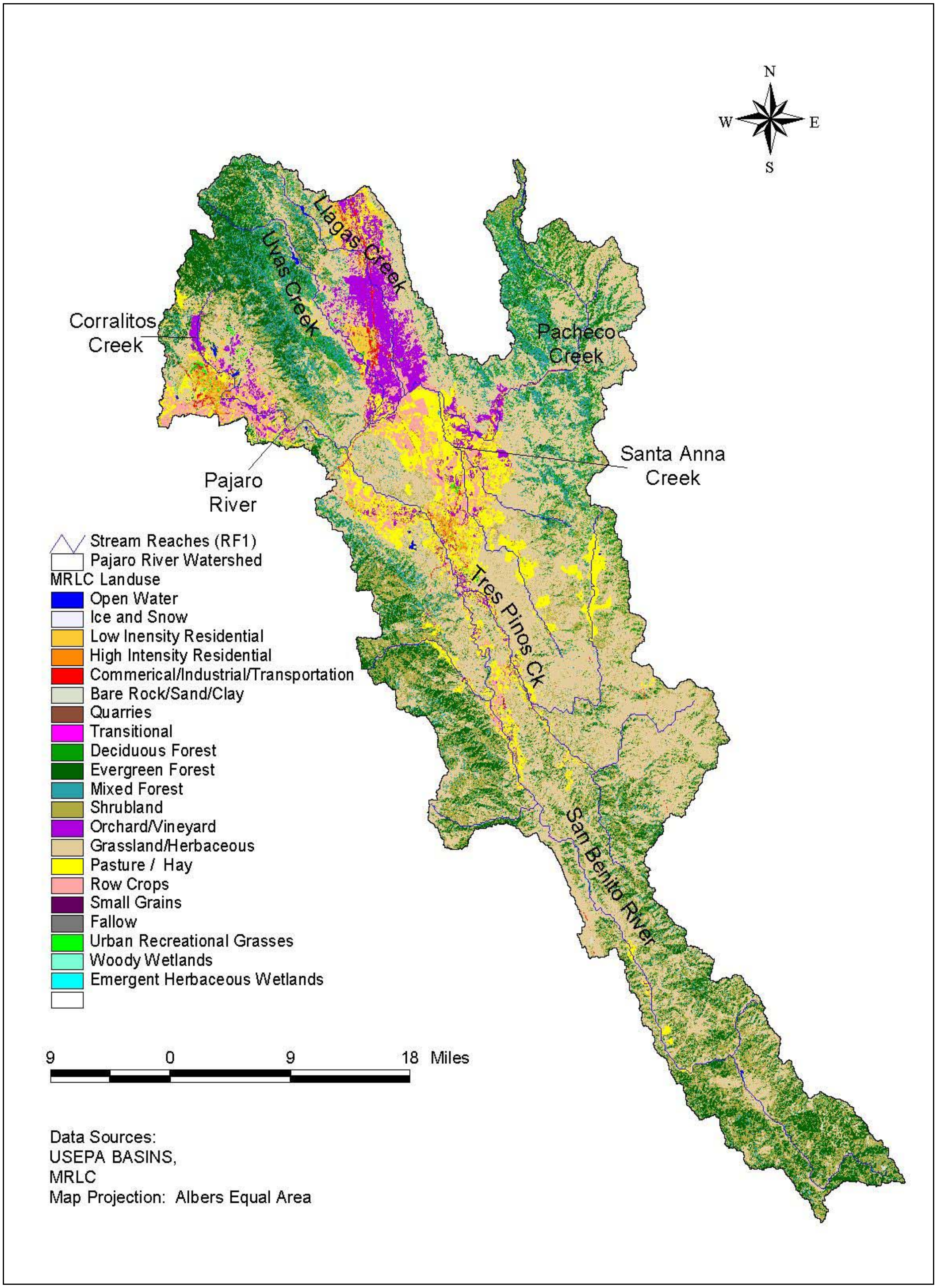



Figure 3-15. MRLC land use coverage in the Pajaro River watershed.

Approximately 92 percent of the land in the Pajaro River watershed is privately owned. The U.S. Bureau of Land Management owns approximately 4.5 percent of the land in the watershed, primarily in the Upper San Benito and Tres Pinos Creek watersheds. Almost 2 percent of the land is owned and operated by the California Department of Parks and Recreation.

## 3.4 Geology

The Pajaro River watershed consists of the rocks of the Eastern Franciscan Block and the Salinian Block along the San Andreas Fault Zone (ASE 1999). The watershed sits in a valley in the California Coastal Range, which consists of the Central and Southern Diablo Ranges, the Santa Cruz Mountains, and the Gabilan Range. The edges of the mountains and the lower hills are characterized by folded younger sediments and by recent flat terraces of older alluvium. Alluvial sediments and terraces characterize the valleys of the watershed.

## 3.5 Meteorological Data

Meteorological data include precipitation data as well as humidity, cloud cover, and temperature. Table 3-10 and Figure 3-16 display the weather stations in or near the Pajaro River watershed with average annual precipitation values. Of these, only the Panoche 2 W and the Santa Maria WSO stations are outside the watershed. On average, Santa Maria receives approximately 15 inches of rainfall per year; Panoche receives approximately 11 inches per year.

The climate in the Central Coast region is influenced by the Pacific Ocean. The region generally has a mild climate with cool summers on the coast, where fog is common, and warm summers in the interior. The city of Salinas, which is 10 miles from the coast, receives annual precipitation of 13.9 inches and has average temperatures of 50 °F in January and 73.9 °F in September.

Table 3-10. Weather Stations located in the Pajaro River Watershed

| Station ID | Station Name | Begin Date | End Date | Elevation (ft) |
|---|---|---|---|---|
| 44025 | Hollister 2 | 1948 | 2001 | 282 |
| 46610 | Paicines 4 W | 1948 | 2001 | 902 |
| 46675 | Panoche 2 W | 1949 | 2001 | 1486 |
| 43417 | Gilroy | 1957 | 2001 | 194 |
| 49473 | Waterworks | 1948 | 2001 | 112 |
| 7946 | Santa Maria WSO | 1948 | 2001 | 249 |
| 111 | Green Valley Road | 1992 | 2001 | 105 |
| 126 | San Benito | 1994 | 2001 | 354 |
| 129 | Pajaro | 1995 | 2001 | 33 |
| 132 | Morgan Hill | 1997 | 2001 | 394 |
| 143 | San Juan Valley | 0 | 2001 | 276 |

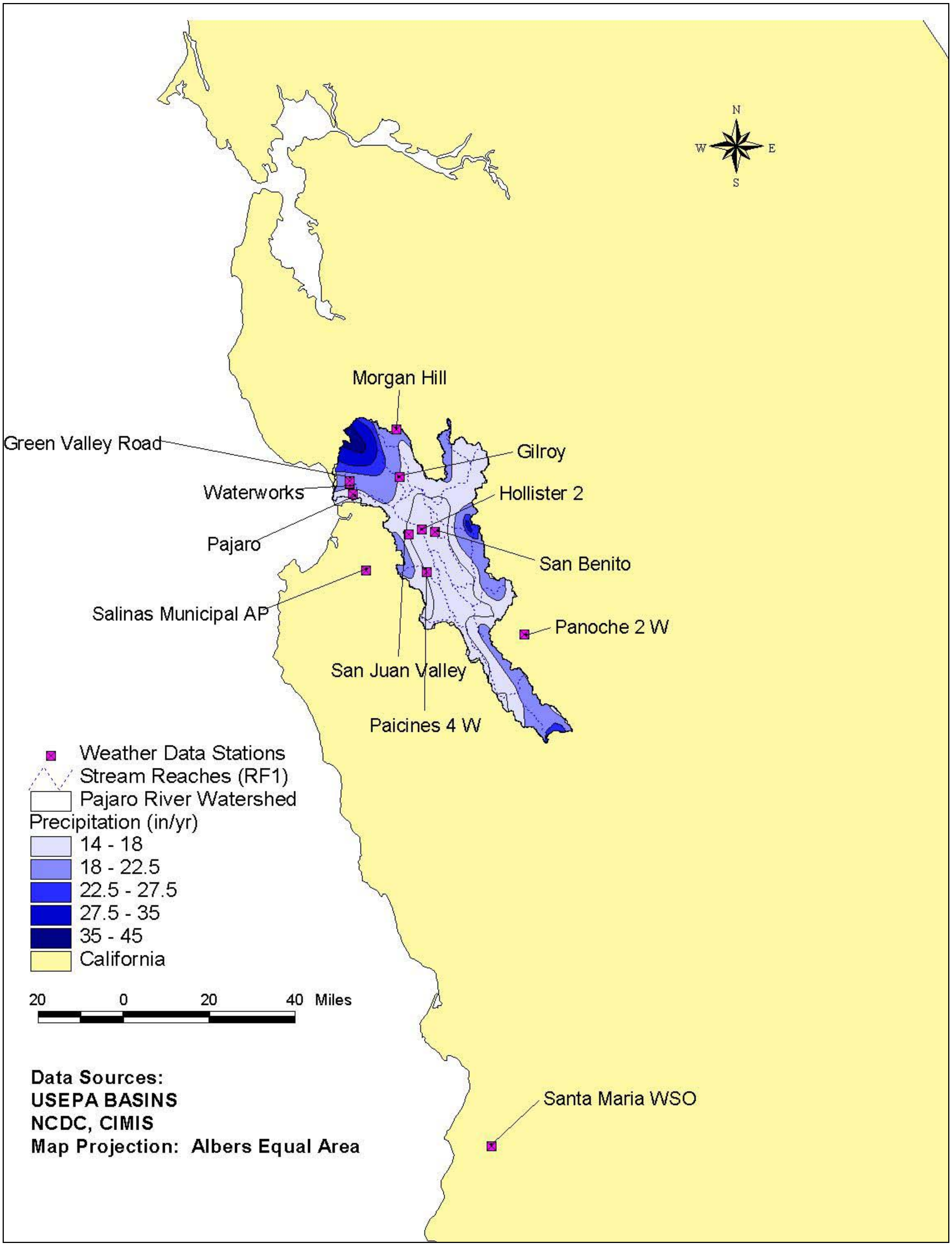



Figure 3-16. Location of weather stations and precipitation patterns.

Table 3-11 displays information on monthly average precipitation at two weather stations. The Salinas Airport and Hollister 2 stations were selected because they contained the most complete data set. This information was compiled from the Western Regional Climate Center (WRCC) and the National Oceanic and Atmospheric Administration (NOAA). The Hollister weather station is near Hollister, California, which is in the middle of the Pajaro River watershed. The Salinas airport weather station is located approximately 10 miles west of the Pajaro River watershed.

Table 3-11. Average Precipitation Data

| | **Weather Station** | |
|---|---|---|
| | **Salinas FAA Airport at Salinas, CA** | **Hollister 2 at Hollister, CA** |
| | **1878—2000 (inches)** | **1948—2000 (inches)** |
| **January** | 2.69 | 2.82 |
| **February** | 2.39 | 2.88 |
| **March** | 2.18 | 2.31 |
| **April** | 1.11 | 0.8 |
| **May** | 0.3 | 0.38 |
| **June** | 0.1 | 0.06 |
| **July** | 0.03 | 0.05 |
| **August** | 0.05 | 0.07 |
| **September** | 0.13 | 0.38 |
| **October** | 0.58 | 0.65 |
| **November** | 1.45 | 1.85 |
| **December** | 2.31 | 1.69 |
| **TOTAL** | **13.32** | **13.94** |

The precipitation data from these two weather stations provide further information about the critical conditions and seasonality in the Pajaro River watershed. In general, higher average precipitation at both stations occurs from November through May while lower average precipitation occurs from June through October. Given the close relationship between precipitation, streamflow, and sediment loading, it is likely that higher sediment loading will occur from November through May.

# 4.0 SOURCE ASSESSMENT

This section examines and identifies the potential sources of sediment in the Pajaro River watershed. Available in-stream and watershed data were used to identify potential sources and to characterize the relationship between point and nonpoint source discharges and the in-stream response at monitoring stations.

## 4.1 Nonpoint Sources

Erosion of the land results in the transport of sediment to receiving waterbodies through various processes. Factors that influence erosion include characteristics of the soil, vegetative cover, topography, and climate. Nonpoint sources, such as agricultural land uses and construction areas, are often large contributors of sediment because the percentage of vegetative cover is typically lower than that on natural areas and these land uses experience more ground-disturbing activities. Urban areas can also contribute sediment to surface waters through buildup and eventual wash-off of soil particles, dust, debris, and other accumulated materials. Pervious urban areas, such as lawns and other green spaces contribute sediment in the same manner as low-intensity pasture areas or other similar land uses. In addition, streambank erosion and scouring processes can result in the transport of additional sediment loads. Timber operations represent another potential source of sedimentation. Although the sediment yield from undisturbed forest is generally low, clear-cut areas can contribute significant sediment loads.

An intensive study of the Pajaro River Watershed (*Pajaro River Watershed Water Quality Management Plan*) was completed in 1999 by Applied Science and Engineering for the Association of Monterey Bay Area Governments. The report provides extensive detail on the major sediment sources to the watershed. The following sections summarize the findings of that study as well as some other local watershed studies. For a more detailed discussion on the sediment sources in the watershed, refer to *Pajaro River Watershed Water Quality Management Plan* (ASE 1999).

### *4.1.1 Agriculture*

Agricultural runoff from cropland and pasture often contributes pollutant loads and sediment to a waterbody when eroded soils are washed into the stream. Irrigated agricultural areas in the Lower Pajaro River watershed result in increased erosion rates that contribute to excess sedimentation (ASE 1999). There do not appear to be significant efforts to control erosion from cropland in the watershed (RMC 2002). In addition, in the Lower Pajaro, farmed row crops often come right to the edge of the streams and drainage ditches adjacent to roads (RMC 2002) and encroachment of croplands has reduced the coverage of riparian vegetation along many of the stream reaches (ASE 1999). Cropland in the watershed is often tilled just a few feet from the upper terraces of the major surface waters, and irrigation ditches and rows are often oriented such that they provide direct runoff pathways to surface waters (SJSU 1994).

Agricultural activities in the upper portions of the Pajaro River watershed are less intensive, and they are not considered to contribute as much to the overall sediment problem as those in the lower areas of the watershed.

### 4.1.2 Silviculture

Silviculture, especially forest harvesting, can be a significant nonpoint source of sediment to waterbodies. Unimproved roads in steep upper watershed areas associated with timber harvest practices are accelerating erosion and sedimentation throughout the watershed. Forest roads are considered the major source of erosion in silvicultured areas. Forest roads account for nearly 90 percent of the total sediment load from forestry operations in the watershed (ASE 1999).

Timber harvesting occurs primarily in the upper watershed areas in Santa Cruz and Santa Clara Counties.

### 4.1.3 Urban/Residential Areas

Sediment from urban and residential nonpoint sources can be carried into streams through surface runoff and through erosion from unpaved areas and disturbed sites. Paved roads are potential sources of sediment in populated areas. The majority of the paved roads in the watershed are included in the urban and transportation land use categories of the MRLC land use coverage (Table 3-3). Urban development in the valley regions of the watershed has resulted in the reduction of riparian vegetation along stream reaches (ASE 1999). However, the percentage of urban development in the watershed is very small; development is not considered to produce significant sediment loads (RMC 2002).

### 4.1.4 Streambank Erosion

The loss of riparian vegetation has left many streambanks unvegetated, causing accelerated erosion from steep and unstable banks (ASE 1999). Channelization and channel-clearing activities associated with flood-control measures have altered and reduced the amount of riparian habitat mainly along the lower Pajaro River and Tres Pinos Creek.

### 4.1.5 Sand and Gravel Mining

Sand and gravel mining along the lower San Benito River has caused significant channel degradation in the watershed (ASE 1999). The riverbed has become highly degraded and is in a state of disequilibrium. The river is deeply incised in several areas and has steep and erodible banks. These conditions result in accelerated erosion and sedimentation to the river.

### *4.1.6 Rangeland/Grazing*

Grazing practices in the Pacheco, Tres Pinos, and San Benito watersheds have reduced coverage of riparian habitat along many of the stream reaches in these areas (ASE 1999); however, grazing appears to be well managed in the majority of the watershed (RMC 2002).

### *4.1.7 Roads*

Paved and unpaved off-road vehicle trails have been found to contribute to erosion and sedimentation in the Pajaro River watershed. Unsurfaced roads are a potential major source of erosion. There are two publicly owned off-highway recreational areas in the Pajaro River watershed: Hollister Hills Recreational Area and the Clear Creek Management Area. Hollister Hills encompasses 114 miles of dirt roads and trails and is in the Pescadero Creek watershed. The Clear Creek Management Area, in the upper portions of the San Benito River, is extensively used for vehicular off-road recreation. Studies of erosion and sedimentation in this area have estimated that the erosion rates from the roads alone are to be more than 25 times the rate from undisturbed soils (PTI 1993).

### *4.1.8 Landslides/Natural Erosion*

Soils and topography in the Pajaro River watershed contribute to naturally high rates of erosion. The Pajaro River watershed lies along one of California's most active fault zones, the San Andreas fault, and many landforms in the watershed are highly unstable (ASE 1999). Most of the steep upper watershed areas have active landslides or are prone to landslides. Landslides are major and mostly uncontrollable sediment sources to the watershed.

## 4.2 Point Sources

A point source, according to 40 CFR 122.3, is defined as any discernible, confined, and discrete conveyance, including any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. The National Pollutant Discharge Elimination System (NPDES) Program, under Clean Water Act sections 318, 402, and 405, requires permits for the discharge of pollutants from point sources.

### 4.2.1 NPDES Permits

There are no point sources permitted to discharge to the Pajaro River. Wastewater treatment plants are active in the watershed; however, these facilities use lagoons or land-application techniques. The San Juan Bautista Wastewater Treatment Plant discharges in the watershed but is not hydraulically connected to the Pajaro River System.

### 4.2.2 Municipal Separate Storm Sewer Systems

In 1990, the U.S. Environmental Protection Agency (USEPA) developed rules establishing Phase I of the NPDES storm water program, designed to prevent harmful pollutants from being washed by storm water runoff into Municipal Separate Storm Sewer Systems (MS4s) (or from being dumped directly into the MS4s) and then discharged from the MS4s into local waterbodies. Phase I of the program required operators of medium and large MS4s (those generally serving populations of 100,000 or greater) to implement storm water management programs as a means to control polluted discharges from MS4s. Approved storm water management programs for medium and large MS4s are required to address a variety of water quality related issues including roadway runoff management, municipal owned operations, and hazardous waste treatment. Operators of large and medium MS4s are required to develop and implement Stormwater Management Plans that address, at a minimum, the following elements:

- Structural control maintenance
- Areas of significant development or redevelopment
- Roadway runoff management
- Flood control related to water quality issues
- Municipally owned operations such as landfills and wastewater treatment plants
- Hazardous waste treatment, storage, or disposal sites
- Application of pesticides, herbicides, and fertilizers
- Illicit discharge detection and elimination
- Regulation of sites classified as associated with industrial activity
- Construction site and postconstruction site runoff control
- Public education and outreach

Phase II of the rule extends coverage of the NPDES storm water program to certain small municipalities with a population of at least 10,000 and/or a population density of greater than 1,000 people per square mile. A small MS4 is defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Storm Water Program. There are no large or medium MS4s in the Pajaro River watershed, but there are small MS4s. The cities in the Pajaro watershed designated as small MS4s are Watsonville, Hollister, Gilroy, and Morgan Hill.

# 5.0 TECHNICAL APPROACH

## 5.1 Model Selection

In selecting an appropriate modeling platform for TMDL development, technical and regulatory criteria were considered and addressed. Technical criteria refer to the model's simulation of the physical system in question, including watershed or stream characteristics and processes and constituents of interest. Regulatory criteria make up the constraints imposed by regulations, such as water quality standards or procedural protocol. The following discussion details the considerations in each of these categories specific to model selection for the Pajaro River watershed.

## 5.2 Technical Criteria

### *5.2.1 Physical Domain*

Representation of the physical domain is perhaps the most important consideration in model selection. The physical domain refers to the focus of the modeling effort - typically either the receiving water itself or a combination of the contributing watershed and the receiving water. Selection of the appropriate modeling domain depends on the constituents of interest and the conditions under which the stream exhibits impairment. For a stream dominated by point source inputs that exhibits impairments only under low-flow conditions, a steady-state approach is typically undertaken. This type of modeling approach focuses only on in-stream (receiving water) processes during a user-specified condition.

For streams affected additionally or solely by nonpoint sources or primarily rainfall-driven flow and pollutant contributions, such as those in the Pajaro River watershed, a dynamic approach is recommended. Dynamic watershed models consider time-variable nonpoint source contributions from a watershed surface or subsurface. Some models consider monthly or seasonal variability, while others enable assessment of conditions immediately before, during, and after individual rainfall events. Dynamic models require a substantial amount of information regarding input parameters and data for calibration purposes.

### *5.2.2 Source Contributions*

Primary sources of pollutants to a waterbody must be considered in the model selection process. Accurately representing point source contributions from permitted sources and nonpoint source contributions from urban, agricultural, and natural areas is critical in properly representing the system and ultimately evaluating potential load reduction scenarios.

Available information regarding sediment loading in the Pajaro River watershed indicates that the main sources are agriculture, irrigated crop production, rangeland, storm runoff, resource extraction, surface mining, hydromodification, channelization, habitat modification, removal of riparian vegetation, streambank modification, and channel erosion. As a result, the model selected to develop sediment TMDLs for the streams in the Pajaro watershed must be able to address the major source categories deemed controllable for implementation purposes.

### 5.2.3 Critical Conditions

The goal of the TMDL is to determine the assimilative capacity of a waterbody and to identify potential allocation scenarios that enable the waterbody to achieve water quality criteria under all conditions. The critical condition is the set of environmental conditions for which controls designed to protect water quality will ensure attainment of objectives for all other conditions. This is typically the time period in which the stream exhibits the most vulnerability. In the Pajaro River watershed, this period coincides with the winter season. In general, higher average precipitation at weather stations in and near the Pajaro watershed occurs from November through May while lower average precipitation occurs from June through October. Analysis of data from USGS monitoring stations shows that high SSC concentrations tend to occur during high-flow periods. For the SWAT modeling analysis, critical conditions in the Pajaro River watershed have been identified to occur between November and May, particularly following storm events.[5]

### 5.2.4 Constituents

Another important consideration in model selection and application is choosing appropriate constituents to simulate. Choice of state variables is a critical part of model implementation. The more state variables included, the more difficult the model will be to implement and calibrate. If key state variables are omitted from the simulation, however, the model might not simulate all necessary aspects of the system and might produce unrealistic results. A delicate balance must be maintained between minimal constituent simulation and maximum applicability.

The focus of TMDL development for the Pajaro River watershed is for sediments. Sediment delivery and transport are extremely complex, and accurate estimation of sediment loading relies on a host of interrelated factors. Multiple factors influence movement of sediment from point of origin into stream channels and throughout a stream network. Sediments can be trapped or stored on hillslopes, as well as in stream channels. These transport and storage mechanisms and their influence on the impairment must be addressed.

Various factors contributing to sediment loading are at work at different locations throughout the Pajaro River watershed. These factors are largely driven by land use and topography, which the model must also take into account.

[5] Summer low-flow conditions have also been identified as coinciding with adverse habitat impacts at the mouth of Rider Creek. These impacts are attributed to bed sediment conditions and should be considered during establishment of additional targets for the Pajaro River sediment impairment.

## 5.3 Regulatory Criteria

A properly designed and applied model provides the source-response linkage component of the TMDL and enables accurate assimilative capacity assessment and allocation distribution. A stream's assimilative capacity is determined through adherence to predefined water quality objectives. The Water Quality Control Plan for the Central Coast Region establishes, for all waters within that region (including the Pajaro River watershed), the beneficial uses for each waterbody to be protected, the water quality objectives that protect those uses, and an implementation plan that accomplishes those objectives. (See Table 2-1.) The Control Plan does not specify numeric water quality criteria for sediment. To accommodate sediment requirements of critical cold water fish species in the watershed, however, a numeric sediment concentration target has been identified based on available information. It is anticipated that additional data collection will be undertaken to verify the appropriateness of this target and for revising the target if necessary

For purposes of TMDL development, the selected target relates to a range of literature-derived sediment dosages, that is, the duration of time for which water column sediment concentrations exceeds a given amount. The modeling platform must enable direct comparison of model results to in-stream concentrations and allow for the analysis of the duration of those concentrations. For the watershed loading analysis and implementation of required reductions, it is also important that the modeling platform enable examination of gross land use loading as well as in-stream concentration.

## 5.4 Soil and Water Assessment Tool (SWAT)

Establishing the relationship between the in-stream water quality targets and source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a number of techniques, ranging from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. The objective of this section is to present the approach taken to develop the linkage between sources and in-stream responses for TMDL development in the Pajaro River watershed.

The Soil and Water Assessment Tool (SWAT) was applied to the Pajaro River watershed to link sediment sources to in-stream indicators, determine existing sediment loads, and calculate the TMDL reductions necessary to achieve the numeric target value for the selected indicator.
The SWAT model is capable of predicting water quantity, water quality, and sediment yields from large, complex watersheds with variable land uses, elevations, and soils. Hydrology in SWAT is based on the water balance equation. Overland flow runoff volume is computed based on the Natural Resources Conservation Service curve number method. Curve numbers are a function of hydrologic soil group, vegetation, land use, cultivation practice, and antecedent moisture conditions. SWAT accounts for sediment contributions from overland runoff through the Modified Universal Soil Loss Equation, or MUSLE (Williams, 1975), which provides

increased accuracy, compared to the original USLE method, when predicting sediment transport and yield.

Because it is physically rather than empirically based, the model requires specific input data, such as weather, soils, land use, and topography. The model can simulate 1- to 100-year time periods and links sediment contributions to specific source areas (e.g., subwatersheds or land use areas). This feature is important in terms of TMDL development and allocation analysis. Details on the SWAT model and its modules can be found in the *Soil and Water Assessment Tool Theoretical Documentation* (Neitsch et al. 2002).

The calibrated SWAT model was used to determine existing sediment loads from the Pajaro River watershed. SWAT model capabilities allow sediment loads to be calculated by subwatershed on a daily, monthly, or yearly basis. Sediment loads can also be tracked back to their sources by subwatershed, type of erosion, and/or land use.

# 6.0 MODEL CONFIGURATION

The SWAT model was configured for the Pajaro River watershed and was used to simulate the watershed as a series of hydrologically connected subwatersheds. Configuration of the model involved subdivision of the Pajaro River watershed into modeling units, followed by continuous simulation of flow and water quality for these units using meteorological, land use, and stream data. The specific pollutant modeled was sediment. This section describes key components of the model and the configuration process in greater detail.

## 6.1 Stream Representation

The SWAT model is capable of simulating in-stream hydrology and sediment transport, both of which are affected by the stream geometry (e.g., width, depth, and channel slope). SWAT automatically calculates the initial stream geometric values based on subwatershed drainage areas, standard channel forms, and elevation. Relationships between drainage area and width and depth have been studied in numerous areas of the United States and have been incorporated into the SWAT code to provide width and depth estimates for each stream segment. The initial channel is specified as a simple trapezoid. Channel slope is calculated from the difference between the top and bottom invert elevations. The stream network, subbasins, and outlets for the Pajaro River watershed SWAT model were generated using the BASINS Automatic Delineation Tool and Digital Elevation Model (DEM) data. The automatically generated stream network was checked for accuracy against both EPA's Reach File Version 3 (RF3) reach network and the National Hydrography Data set stream reach network for the Pajaro River watershed.

## 6.2 Subwatershed Delineation

To represent loadings and resulting concentrations of sediment in the impaired waterbodies, the Pajaro River watershed was divided into 24 subwatersheds. Subdivision of the watershed enables the model to reflect differences in hydrology and evapotranspiration for different land covers, crops, and soil groups. The 24 modeled subwatersheds, shown in Figure 6-1, represent physical hydrologic boundaries. The division was based on elevation data (30- by 30-meter DEM), stream connectivity (from RF3), and locations of monitoring stations.

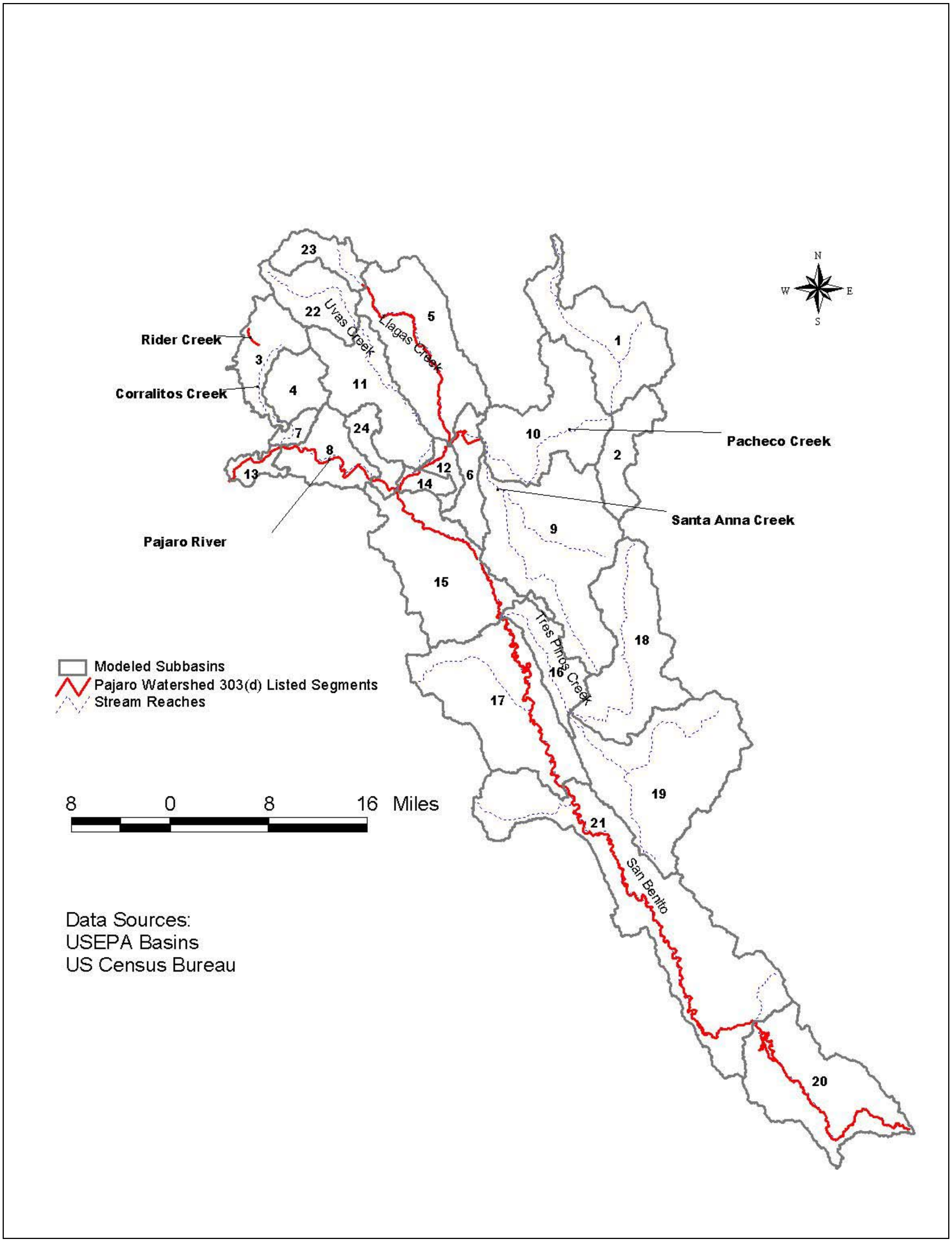



Figure 6-1. Modeled subbasins in the Pajaro River watershed.

## 6.3 Nonpoint Source Representation

Based on analysis of the water quality data for the Pajaro River, as well as review of previous studies in the watershed, possible nonpoint sources of sediment include agriculture, silviculture, urban/residential areas, roads, streambank erosion, sand and gravel mining, rangeland, and landslides. With the exception of landslides, the SWAT model can represent each of these sources.

### *6.3.1 Land uses*

Land use data used to configure the Pajaro River watershed SWAT model were obtained from the Multi-Resolution Land Characterization (MRLC 1992) database and subsequently grouped into SWAT land use categories. Table 6-1 shows the original MRCL land use categories for the watershed and the corresponding SWAT grouping. Landslide prone areas are represented by the barren and bare rock/sand/clay MRLC land use categories. Generally, roads are accounted for in the Pajaro River watershed SWAT model through the UCOM land use category (High-Intensity Commercial/Industrial/Transportation from MRLC). This coverage does not provide an accurate representation of road densities, especially unpaved roads, for areas of the watershed where roads and unpaved roads are known to contribute significantly to sediment loading (Clear Creek, Hollister Hills, and Rider Creek). To better represent the loading from these areas, additional road density information was obtained. The U.S. Census Bureau's Tiger 2000 roads coverage was used to represent roads in the Rider Creek watershed (see Figure 8-2). Additional study data provided estimates of road mileage specifically in the Clear Creek and Hollister Hills areas (ASE 1999).

For subbasins with significant road-related sediment contributions, roads were assumed to be evenly distributed throughout the subbasin. The total area of unpaved roads in subbasins 3, 15, and 20 was calculated based on length and width estimates.[6] The percentage of the subbasin covered by unpaved roads was calculated and assumed to be evenly distributed throughout the predominant landuse type, either forest or rangeland depending on the watershed. Based on the estimated percentage of unpaved roads, the USLE C factor for the predominant landuse was increased to reflect the additional loading potential. The SWAT model was run using the normal C values for the predominant landuse and again using the updated C values for the predominant landuse. Sediment contribution from roads was then determined based on the difference in loading rates between the normal C value run and the updated C value run. Table 6-2 provides a summary of the C values used in each area. In the Clear Creek area, unpaved roads are estimated to comprise approximately 1 per cent of the area; in Rider Creek, .07 per cent; and in Hollister Hills, 1.1 per cent.

[6] Total unpaved road length estimates were obtained from study data (Clear Creek and Hollister Hills) or the US Census Bureau Tiger roads coverage (Rider Creek). Road widths are assumed to be 2-3 meters.

### 6.3.2 Soils

Soil detachment by rainfall on the contributing land uses is simulated in the SWAT model. Detached sediment is removed by surface flow and is washed off into the stream reach, where it eventually settles or is resuspended in the water column. Soils data were obtained from the Natural Resources Conservation Service (NRCS) State Soil Geographic Database (STATSGO).

### 6.3.3 Hydrologic Response Units

Each delineated subwatershed was further subdivided using a soils/land use overlay process to generate Hydrologic Response Units (HRUs). An HRU consists of a unique combination of land use/land cover, soil, and land management practice characteristics, and thus represents areas of similar hydrologic response. Individual land parcels included within an HRU are expected to possess similar hydrologic and load generating characteristics and can thus be simulated as a unit. These soil/land use combinations are then assigned appropriate curve numbers and other physical and chemical parameter values.

Soils associated with a given land use within a subwatershed were only included if they represent at least 10 percent of the area in that land use in a subwatershed. No threshold was set for land use because densely developed areas may occupy a small area of the watershed but can have significant pollutant contributions. 644 individual HRUs were simulated in the Pajaro River watershed.

### 6.3.4 Channel Erosion

Streambank and channel erosion in the watershed can be accounted for through the use of the SWAT sediment channel routing module. This module accounts for sediment deposition and degradation in the stream channel. The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity. Depending on the flow velocity, in-stream sediment is either transported to the next stream segment or deposited in the channel. If flow velocity is high while there is not enough sediment supply from land, channel erosion will occur. The amount of channel erosion is dependent on the available sediment transport capacity or flow, channel vegetation cover, and channel erodibility.

Table 6-1. Modeled Land use Categories (source: MRLC)

| MRLC Code | MRLC Description | SWAT LAND USE |
|---|---|---|
| 83 | Small Grains | AGRC |
| 80 | Herbaceous Planted/Cultivated | AGRL |
| 82 | Row Crops | AGRR |
| 33 | Transitional | BTRS |
| 84 | Bare Soil (Fallow) | FALW |
| 41 | Deciduous Forest | FRSD |
| 42 | Evergreen Forest | FRSE |
| 40 | Natural Forested Upland | FRST |
| 43 | Mixed Forest | FRST |
| 32 | Quarries/Strip Mines/Gravel | MINE |
| 0 | Unclassified | NOCL |
| 60 | Non-Natural Woody | ORCD |
| 61 | Planted/Cultivated (orchard) | ORCD |
| 81 | Pasture/Hay | PAST |
| 85 | Urban/Recreation Grasses | PAST |
| 50 | Natural Shrubland | RNGB |
| 51 | Deciduous Shrubland | RNGB |
| 52 | Evergreen Shrubland | RNGB |
| 53 | Mixed Shrubland | RNGB |
| 70 | Herbaceous Upland Natural/Semi Natural | RNGE |
| 71 | Grassland/Herbaceous | RNGE |
| 30 | Barren | ROCK |
| 31 | Bare Rock/Sand/Clay | ROCK |
| 12 | Perennial Ice/Snow | SNOW |
| 23 | High Intensity Commercial/Industrial/Transportation | UCOM |
| 22 | High Intensity Residential | URHD |
| 21 | Low Intensity Residential | URLD |
| 20 | Developed | URMD |
| 10 | Water | WATR |
| 11 | Open Water | WATR |
| 91 | Woody Wetlands | WETF |
| 90 | Wetlands | WETL |
| 92 | Emergent Herbaceous Wetland | WETN |

Table 6-2. USLE C values used in determining road-related loading

| | | Rangeland | Forest |
|---|---|---|---|
| USLE C factor | | 0.006 | 0.001 |
| USLE C factor for subbasins with roads | Clear Creek | 0.0124 | 0.0075 |
| | Hollister Hills | 0.0124 | 0.0075 |
| | Rider/Corralitos area | 0.0065 | 0.0015 |

## 6.4 Point Source Representation

There are no traditional permitted point sources of sediment in the Pajaro River watershed. As part of Phase II of the NPDES storm water permitting program, operators of MS4s in Watsonville, Hollister, Gilroy, and Morgan Hill are required to adopt storm water management programs to control entry of pollutants to local waterways. Any loads associated with these MS4s must be incorporated into the TMDL as part of the Waste Load Allocation (WLA).

Figure 6-2 shows the location of the US Census Bureau-designated "urban boundaries" in relation to the modeled subbasins. It is assumed that the "urban" land uses within these boundaries roughly correspond to the location of areas affected by the Phase II NPDES storm water program. MS4 sediment loads therefore, are considered to be the loads emanating from urban land uses within US Census Bureau-designated urban boundaries. Land uses within the designated urban boundaries are shown in Table 6-3, the urban land uses are highlighted in gray.

In some cases, urban area boundaries extend over multiple modeled subwatersheds. For example, portions of Gilroy and Morgan Hill are located in subbasins 5 and 11. For allocation purposes, the appropriate loads were applied to the related subbasin. Sediment loads from these areas were determined in the same manner as other nonpoint loads. Again, for purposes of the TMDL, these loads will be presented as WLAs, even though they are nondiscrete in nature. They are presented as WLAs because they are to be associated with a permit.

Table 6-3. MRLC Land Use Categories Within Phase II MS4 Urban Boundaries

| **Category** | **Watsonville** | **Gilroy/Morgan Hill** | **Hollister** |
|---|---|---|---|
| Open Water | 704,078 | 16,219 | 0 |
| Low Intensity Residential | 5,027,767 | 20,505,084 | 5,458,991 |
| High Intensity Residential | 1,854,645 | 103,990 | 2,023,509 |
| Commercial/Industrial/Transportation | 812,838 | 5,320,656 | 1,418,651 |
| Bare Rock/Sand/Clay | 377,798 | 187,945 | 656,376 |
| Quarries/Strip Mines/Gravel Pits | 0 | 22,897 | 9,540 |
| Decidiuous Forest | 129,749 | 513,271 | 24,805 |
| Evergreen Forest | 1,836,518 | 348,223 | 22,897 |
| Mixed Forest | 104,944 | 1,312,753 | 18,127 |
| Bare Soil | 0 | 0 | 0 |
| Shrubland | 932,093 | 1,366,179 | 733,653 |
| Orchards/Vineyards/Other | 3,025,246 | 28,131,644 | 823,333 |
| Grasslands/Herbaceous | 10,929,430 | 16,590,677 | 1,910,933 |
| Pasture/Hay | 3,578,587 | 9,688,230 | 8,667,412 |
| Row Crops | 4,274,079 | 5,157,516 | 2,545,367 |
| Urban/Recreational | 629,663 | 506,593 | 637,296 |
| Emergent Herbaceous Wetlands | 0 | 954 | 0 |
| Total (square meters) | 34,217,435 | 89,772,829 | 24,950,889 |
| *Subbasins* | *3, 4, 7, 8, 13* | *5, 11* | *6, 9, 15, 16* |

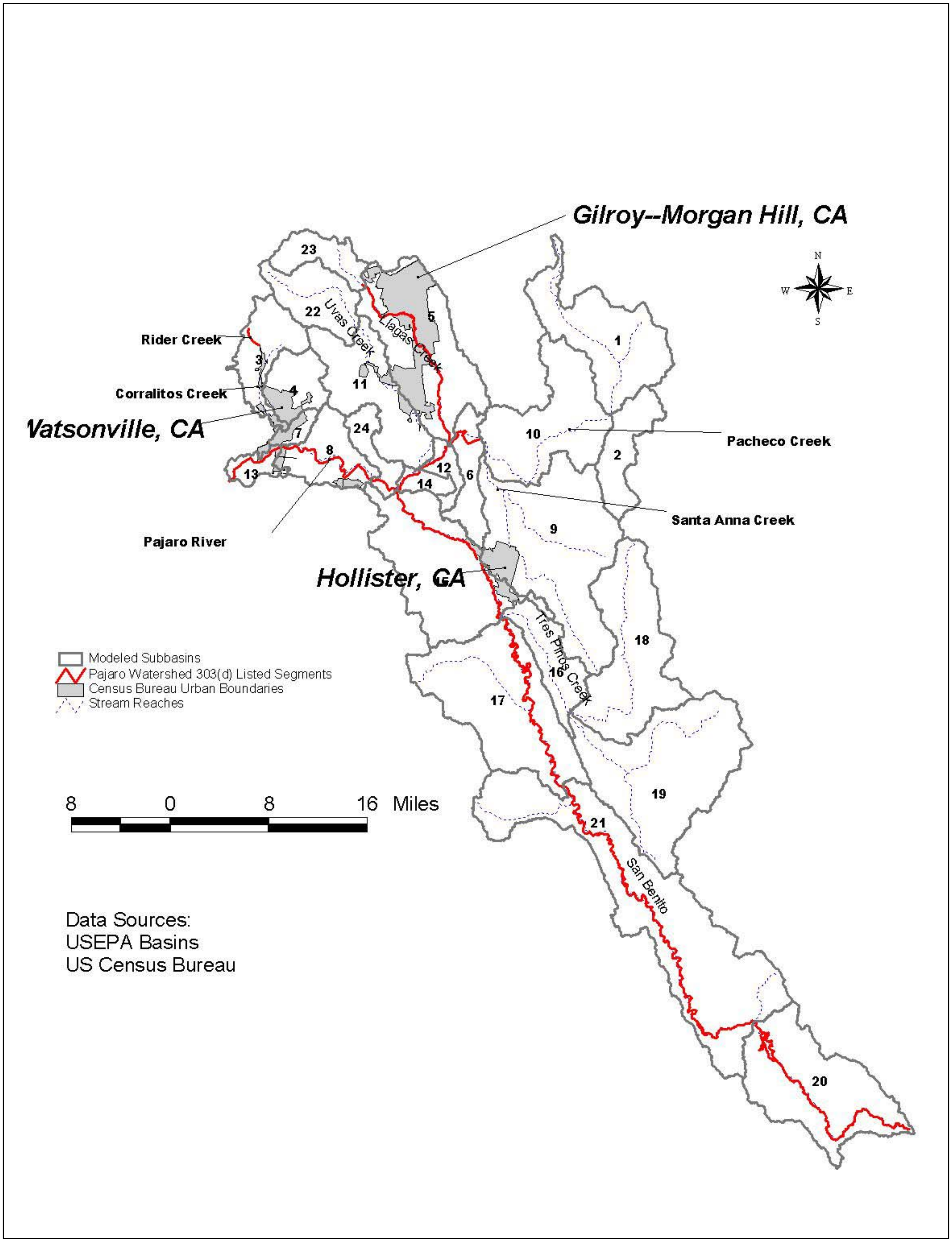



Figure 6-2. Urban boundaries associated with MS4 permits.

## 6.5 Weather Representation

SWAT requires the following climatic inputs: daily precipitation, maximum/minimum air temperature, solar radiation, wind speed, and relative humidity. The model can use observed values for the above parameters or it can generate the necessary data during the simulation based on underlying weather databases and statistical algorithms. The weather generator can be used in conjunction with observed climatic data to fill in any missing observations.

Observed climatological data from five area weather stations (Table 6-4) were used to drive the Pajaro SWAT simulation. SWAT automatically assigns weather station data to a particular subbasin based on the subbasin's proximity to the weather station. Solar radiation data were from the Santa Maria WSO station, approximately 95 miles south of the southern tip of the watershed. Other stations nearby with solar radiation data included San Francisco and Fresno. Radiation data from the Santa Maria station were used because they are assumed to better representative of the conditions of the Pajaro watershed. To account for the distance from the Pajaro watershed, solar radiation time series data from Santa Maria were adjusted using a correction factor of 0.95.[7] Temperature and precipitation data from the remaining stations were applied to various model subbasins of the watershed based on proximity. These data were obtained from the National Climatic Data Center and from Marc Los Huertos, of the University of California, Santa Cruz.

Table 6-4. Weather Stations Used for Climate Data

| Station ID | Station Name | Begin Date | End Date | Elevation ft. |
|---|---|---|---|---|
| 44025 | Hollister 2 | 1948 | 2001 | 282 |
| 46610 | Paicines 4 W | 1948 | 2001 | 902 |
| 46675 | Panoche 2 W | 1949 | 2001 | 1486 |
| 49473 | Watsonville Waterworks | 1948 | 2001 | 112 |
| 7946 | Santa Maria WSO | 1948 | 2001 | 249 |

## 6.6 Modeling Assumptions and Limitations

A number of factors, data limitations, and assumptions must be noted regarding the setup of the Pajaro River watershed SWAT model.

Precipitation in the Pajaro watershed is highly variable, averaging approximately 45 inches per year in areas near the coast and 14 inches per year in the valley. It is assumed that the use of data from the selected weather stations provides sufficient variability in rainfall coverage to accurately simulate sediment loading in the watershed.

7 Solar radiation at Santa Maria, which is farther south, is expected to be slightly more intense than that in the Pajaro River watershed. The correction factor was estimated by comparing total annual solar radiation of the stations surrounding the watershed.

Major sediment loading in this region is associated with high-runoff-generating precipitation events which might occur, on average, once in a period of several years (Watson 2003). Although the SWAT model is not designed to simulate detailed, single-event flood routing, running the model for extended simulation periods should enable accurate prediction of gross loading over the long term.

Subwatershed delineations were based on topographic data. Data regarding flow diversions to or from other watersheds were not available and therefore not considered in the analysis. The model assumes the basic operation unit is the HRU. (See Section 6.3.3.) An HRU represents each of the unique combinations of soil and vegetation/land use in a subwatershed. A subwatershed may have one HRU to hundreds of HRUs. Within a subwatershed, the same combinations of soil and vegetation/land use are lumped into a single type of HRU, disregarding their spatial locations. For the Pajaro River watershed study, all land use types were included but only soils that cover more than 10 percent of the watershed were included.

Landslides are not considered explicitly in the model; however, areas associated with landslides and their sediment generating characteristics are represented by specific land use categories in SWAT. For crop management scenarios, only one land cover or crop type can be “grown” at one time in an HRU. Because land uses drive sediment loading in the SWAT model, assumptions regarding land management practices are critical. Watershed sediment yield is transferred through the stream network to the watershed outlet or deposited in the stream as channel deposition. SWAT does not simulate other storage mechanisms such as hillslope storage.

SWAT produces model results on a daily, monthly, or yearly basis. Hourly simulation is not possible, and therefore single storm events are not considered. Based on the indicator and target value (duration of water column sediment concentrations), daily average concentration estimates were deemed sufficient.

SWAT assumes one-dimensional, well-mixed streams and reservoirs. Reservoirs were simulated in subbasin 1 (Pacheco Lake), 4 (College Lake), 5 (San Felipe Lake), 16, Hernandez Reservoir), 19 (Chesbro Lake), and 20 (Uvas Reservoir). The water release rates of reservoirs were set to the average daily flow rate of the subbasin when water levels are within the capacity of the reservoirs. This assumption may impact the simulated flow and sediment concentration if the actual water release rates are significantly different from the average daily flow rate. SWAT assumes that channel (bank and bed) erosion is related to flow rate, channel erodibility, and channel vegetation cover. Because of the large scale of the Pajaro River watershed model, channel erosion estimates are not reliable; therefore, stream channel erosion is not given a specific allocation in this study.

# 7.0 MODEL CALIBRATION

After the model was configured, calibration was performed for the Pajaro River watershed. Calibration refers to the adjustment or fine-tuning of modeling parameters to ensure that model output matches observed data as closely as possible. It is typically a two-phase process: hydrology calibration is performed first, followed by water quality calibration.

Hydrology is the first model component calibrated because estimation of sediment contributions relies heavily on flow prediction. The hydrology calibration involves a comparison of model results to in-stream flow observations at selected locations and the subsequent adjustment of hydrologic parameters. The Pajaro River watershed SWAT model was calibrated at three locations (Corralitos Creek, Clear Creek, and Pajaro River at Chittenden) for which sufficient flow and limited sediment data were available. Figure 7-1 shows these stations. For water quality calibration, suspended sediment concentration data were compared to model output. Suspended sediment concentration data are considered more representative of in-stream sediment conditions than TSS data (Gray et al. 2000).

After calibration, model parameters were validated. Model validation refers to the testing of calibration adequacy through application of parameters to an independent data set (without further adjustment). In this case, the calibrated model parameters were used to simulate a time period other than the calibration period for each calibration location. Model outputs were analyzed to determine whether the model predictions for the validation period are accurate when compared to observed data. After validation, the calibrated data set containing parameter values for modeled sources and pollutants was then applied to the entire watershed. Time periods selected for calibration and validation were dependent upon availability of observation data.

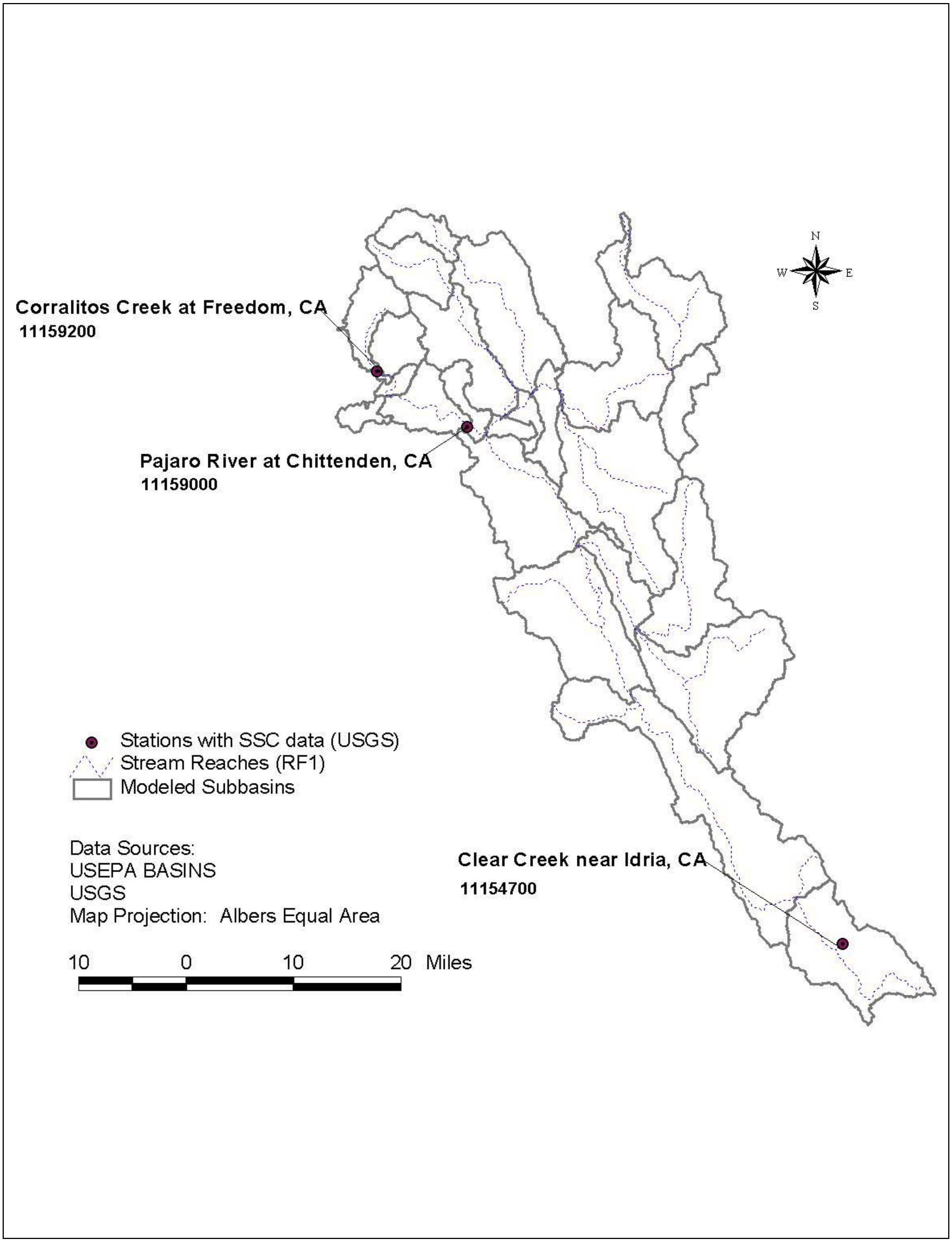



Figure 7-1. Calibration locations.

The same basic steps were taken to set up, run, and calibrate the model at each location. Using the BASINS 3.0 application for watershed characterization, analysis, and modeling, a base project was created. The Automatic Delineation Tool was used to create model subwatersheds using a 30- by 30-meter DEM grid coverage. Necessary data themes were added to the project (MRLC land use, STATSGO soils, National Hydrography Data set). A spatial overlay of the land use and soils themes established the HRUs . Next, weather stations were designated and the input files were automatically generated using ArcView extensions included with the SWAT BASINS 3.0 application. The SWAT model was run to obtain the default results.

Model output was then processed with the aid of Microsoft Excel macros developed to facilitate the calculation of necessary parameters and provide graphic interpretation of results. After comparison of the model results to observed data, various model parameters were adjusted to produce better agreement between output and observations. Table 7-1 shows the parameters adjusted at each location during the calibration process. Results were compared to observations at daily and monthly time steps; multiyear, monthly mean results were also analyzed. The following paragraphs present the calibration and validation results for each location.

Table 7-1. SWAT Parameters Adjusted During Calibration

| SWAT Parameter | Calibration Location | | |
|---|---|---|---|
| | Corralitos Creek | Clear Creek | Pajaro R. at Chittenden |
| Slope length | ● | ● | ● |
| Ground water recharge coefficient | ● | ● | ● |
| Ground water delay time | ● | ● | ● |
| Ground water re-evapotranspiration coefficient | ● | ● | ● |
| Ground water minimum depth for re-evapotranspiration | ● | | ● |
| Slope value | ● | ● | ● |
| Soil hydrologic conductivity | ● | | |
| Curve number | | ● | ● |
| Soil available water capacity | | ● | |
| Overland transport coefficient | ● | ● | ● |
| Surface water delay | ● | ● | ● |
| Crop database for erosion factor | ● | ● | ● |

## 7.1 Corralitos Creek Calibration

The Corralitos Creek watershed is in the northwestern portion of the Pajaro River watershed as shown in Figure 7-2. Major land uses are forest (59 per cent), rangeland (30 per cent), orchard (6 per cent) and low-density residential (4 per cent). The remaining one per cent is made up of various other minor land use categories. Rider Creek, included on the Section 303(d) list for sedimentation/siltation, is in the Corralitos Creek watershed.

Weather data used to drive the model for calibrating the Corralitos Creek watershed were taken from CA 9473, Watsonville Waterworks (temperature and precipitation) and 7946, Santa Maria

WSO (solar radiation). The proportion of base-flow to surface runoff was calculated for USGS gage 11159200 at Freedom, using the SWAT base-flow filter program and USGS flow data from 1956-2001. Base-flow represents approximately 32 per cent to 52 per cent of the total annual flow. Water yield, which represents the total annual streamflow generated by precipitation, is approximately 32 per cent of precipitation based on observation data.

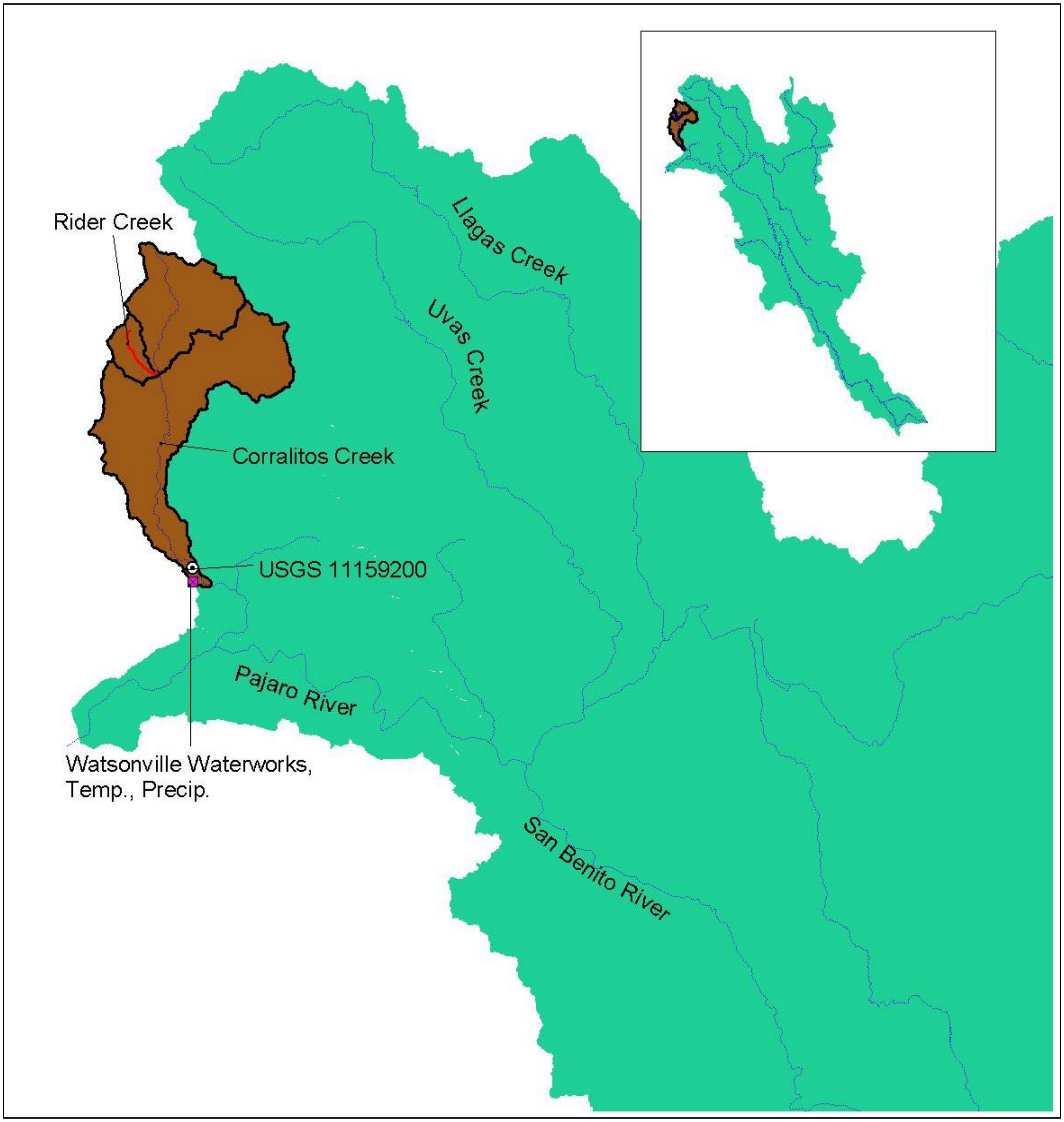



Figure 7-2. Location of Corralitos Creek watershed.

### 7.1.1 Hydrology Calibration (Corralitos Creek)

Daily simulation results match rainfall events and most USGS flow events with respect to time, peaks, and duration. Figure 7-3 shows modeled vs. observed flows for the calibration period from October 1, 1981, to September 30, 1984. The flow calibration was validated for the period November 11, 1992, to September 7, 1993 (Figure 7-4).

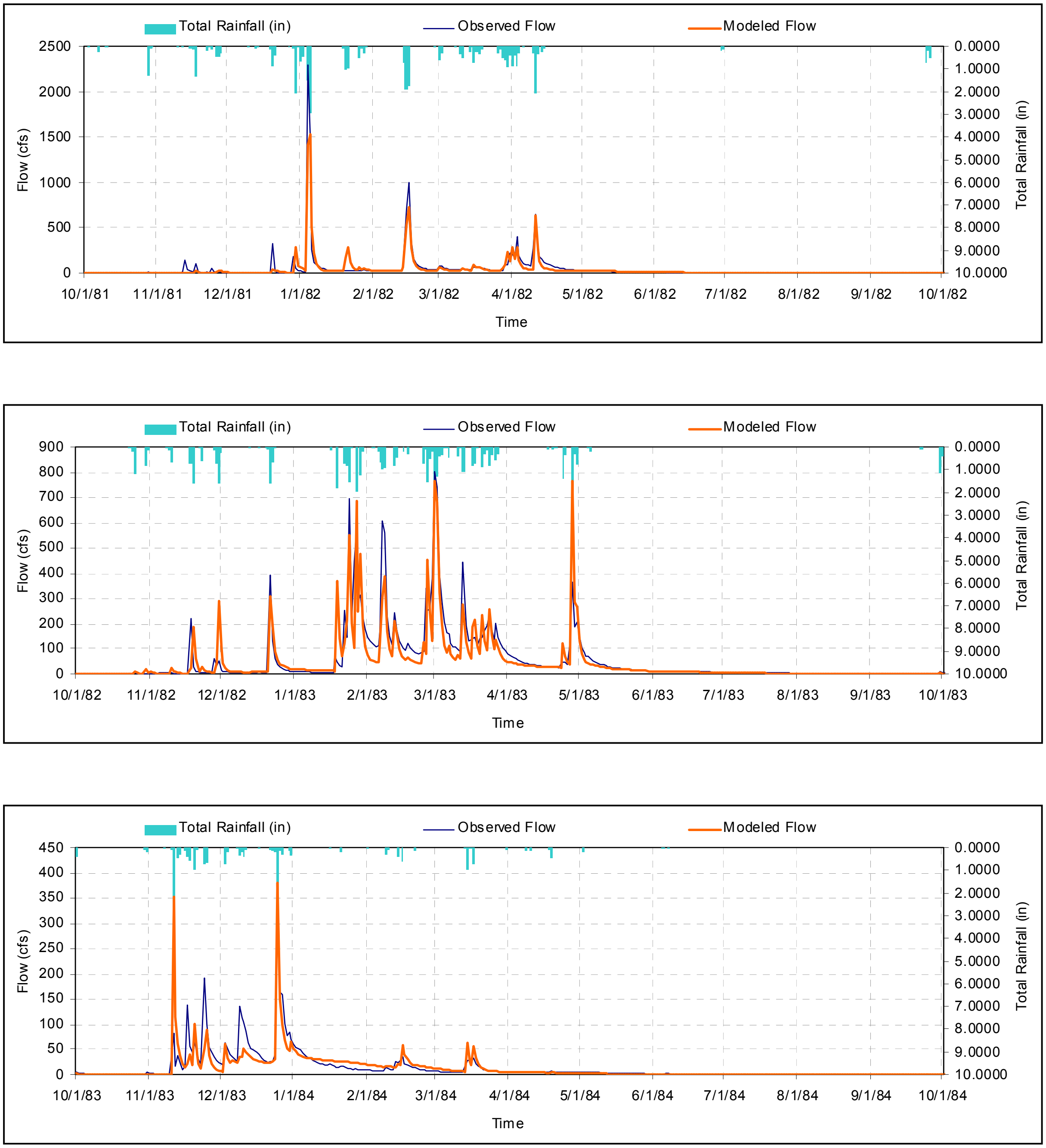



Figure 7-3. Hydrology calibration, Corralitos Creek at Freedom, 10/1/1981 to 10/1/1984.

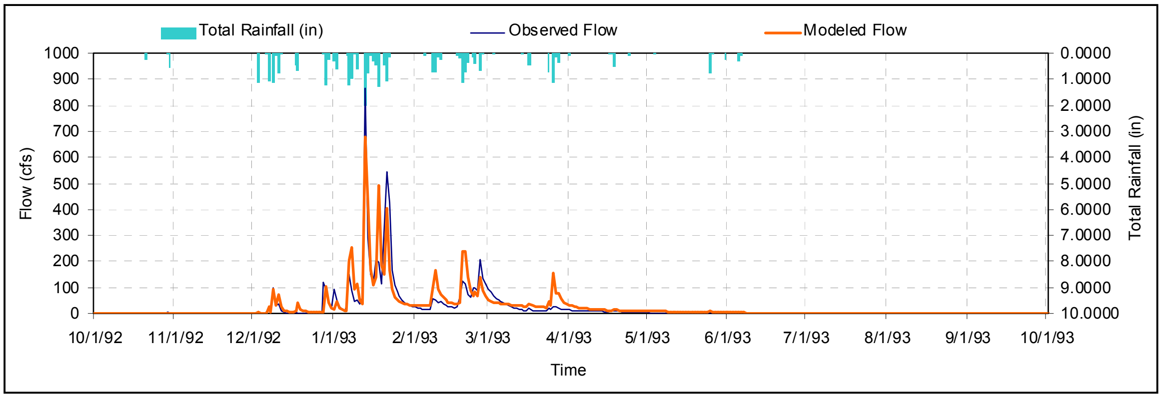



Figure 7-4. Hydrology validation, Corralitos Creek at Freedom, 11/11/1992 to 9/7/1993.

Monthly and weekly analyses show that calibrated model flow results are strongly correlated with observed values. For water year 1982, a regression of monthly modeled flow vs. observed flow yields an $R^2 = 0.9584$; for weekly flows, $R^2 = 0.9635$. Figure 7-5 displays monthly and weekly modeled and observed flow. Precipitation is displayed on the top axis.

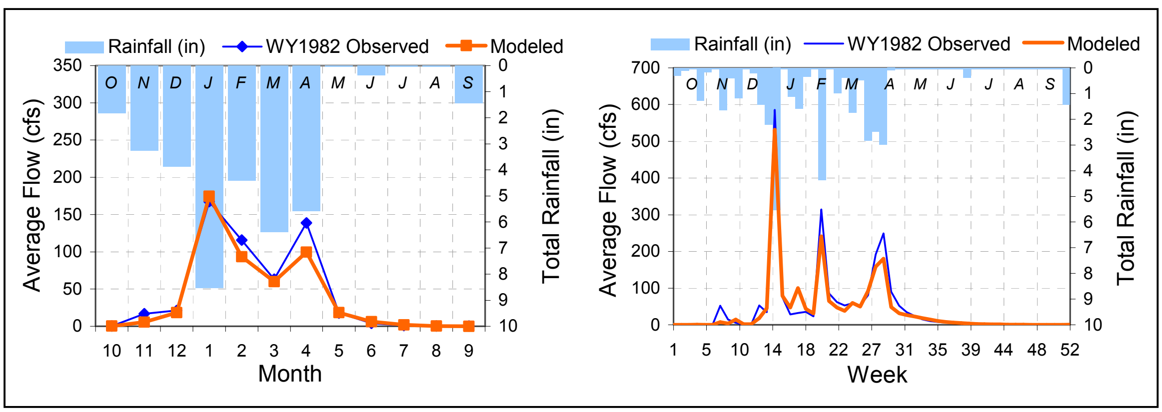



Figure 7-5. Monthly and weekly modeled and observed flow, with precipitation, WY 1982.

A continuous model simulation was performed for the period 1980 to 2001. Figure 7-6 shows the results of this simulation. Note that the SWAT model reports data in metric units. Precipitation is shown along the top axis in millimeters (1 inch = 25.4 mm). The USGS estimation of flow (in cubic feet per second) is converted to millimeters by dividing the flow volume by the watershed area to obtain the depth of water over the watershed (Figure 7-7).

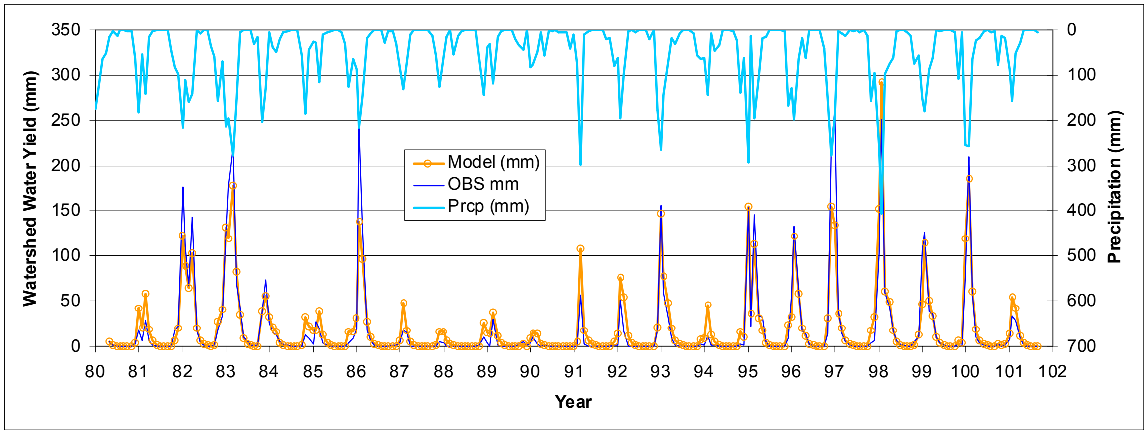



Figure 7-6. Monthly calibration results from continuous simulation (1980—2001).

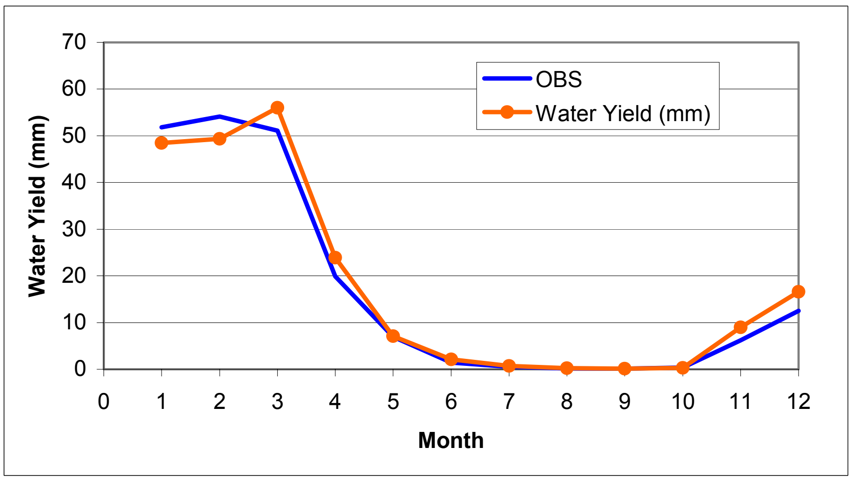



Figure 7-7. Corralitos Creek, mean monthly water yields (modeled vs. observed, 1980—1995).

### *7.1.2 Water Quality Calibration (Corralitos Creek)*

Limited flow and suspended sediment data were available for the USGS gage on Corralitos Creek (see Table 3-4).[8] Using the U.S. Army Corps of Engineer's FLUX program, which allows for estimating loadings from sample concentration data and a continuous flow record, these data were used to estimate the sediment load in Corralitos Creek (Walker 1999). Additional information can be obtained at the following Website: http://www.wes.army.mil/el/elmodels/emiinfo.html. Based on FLUX regression methods, average annual sediment loading in Corralitos Creek is estimated to range from 9,946 to 16,535

8 Regression of instantaneous flow and SSC yields an $R^2 = 0.7484$

metric tons or 397 to 661 U.S. tons per square mile. The FLUX-generated sediment values were used to augment available observed data for the calibration process.

After calibration, the SWAT model for the Corralitos Creek watershed estimates an annual average load of 16,608 metric ton per year or 663 US tons per square mile per year, which matches well with the FLUX-generated estimate of average annual loading. Figure 7-8 shows the annual variation of sediment load, comparing the model-simulated load with that estimated by FLUX. The total simulated sediment load from 1/1/1980 to 9/30/2001 is 355,184 metric tons, which is very close to that (359,629 metric tons) estimated using the USGS data and FLUX program.

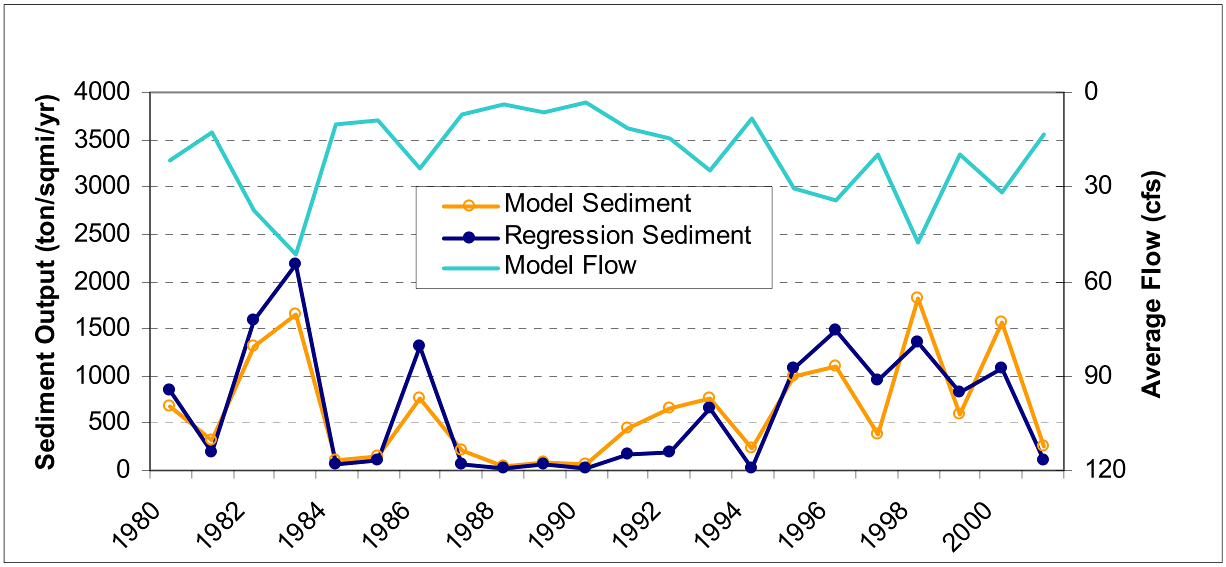



Figure 7-8. Annual variation in sediment load, Corralitos Creek at Freedom.

In addition to FLUX-generated estimates, local watershed studies have also assessed sediment yields in Corralitos Creek. In 1996, annual sediment yield for Corralitos Creek at Freedom was estimated to range from 80 to 5570 US tons per square mile using various analysis methods. The Pajaro River watershed SWAT model estimation is within this range. The sediment exported from Rider Creek was estimated as 195 US tons per square mile per year or 299 metric tons per year (ASE, 1999).

The simulated daily sediment concentration is shown in Figure 7-9. The concentration ranges from 0 to 3,310 mg/L, which overlaps with the limited USGS observations (suspended sediment: from 4 to 3,830 mg/L). Very limited PVWMA turbidity data (total suspended sediment TSS estimated using an regression equation) show that TSS ranges from 0.4 to 1,500 mg/L.

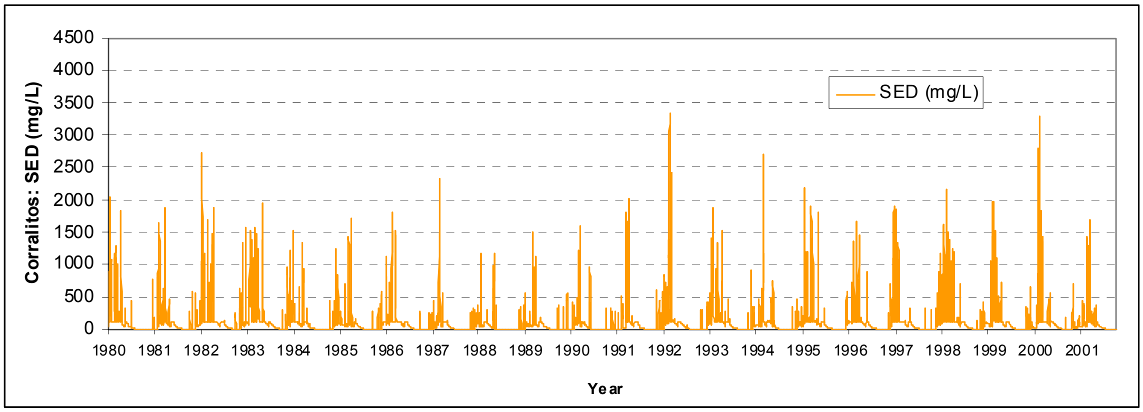



Figure 7-9. Simulated daily SSC, Corralitos Creek at Freedom.

Loading for Rider Creek, because it is specifically included on the 303(d) impairment list was also examined during the Corralitos Creek calibration process. The average annual Rider Creek sediment load simulated by SWAT was 314 metric tons or 205 U.S. tons per square mile per year. WRC Environmental in the *Rider Creek Sediment Management Plan* (1991), estimated sediment loading in Rider Creek to be approximately 331 tons per year or 195 tons per square mile per year. These numbers show excellent agreement. However, the report stipulates the estimates were developed abstractly from visual inspection of sites under dry, non-eroding conditions, and that actual rates may be as much as 10 times higher (i.e. approx 1,950 tons per square mile per year). WRC Environmental also attributed approximately 50 per cent of this loading to human-induced sources, mostly road-related. To reflect this, the model was adjusted by accounting for extra sediment production related to roads in the watershed (see Section 6.3.1 for more discussion of road related loading adjustments). The SWAT model simulates the daily fluctuation of /sediment concentration, which ranges from 0 to 3,810 mg/l. The average annual sediment concentration ranges from 20 to 60 mg/L (1980-2001).

## 7.2 Clear Creek Calibration

The Clear Creek watershed (Figure 7-10), approximately 14 square miles, is near the southern tip of the Pajaro River watershed. Major land uses are forest (45.85 per cent) rangeland (42.2 per cent), and barren (11.14 per cent). The remaining one per cent is made up of various other minor land use categories.

Weather data used to drive the model for calibrating the Clear Creek watershed were taken from CA46610, Paicines 4W (temperature); CA46675, Panoche 2W (precipitation); and 7946 Santa Maria WSO (solar radiation).

The proportion of base-flow to surface runoff was calculated for USGS gage 11154700 near Idria, using the SWAT base-flow filter program and USGS flow data from 10/1/1993--9/30/2001. Base-flow represents approximately 67 per cent of the total annual flow, reflecting a much drier climate in relation to that of Corralitos Creek. Water yield, total annual flow generated by precipitation, is approximately 37 per cent of annual precipitation based on observation data.

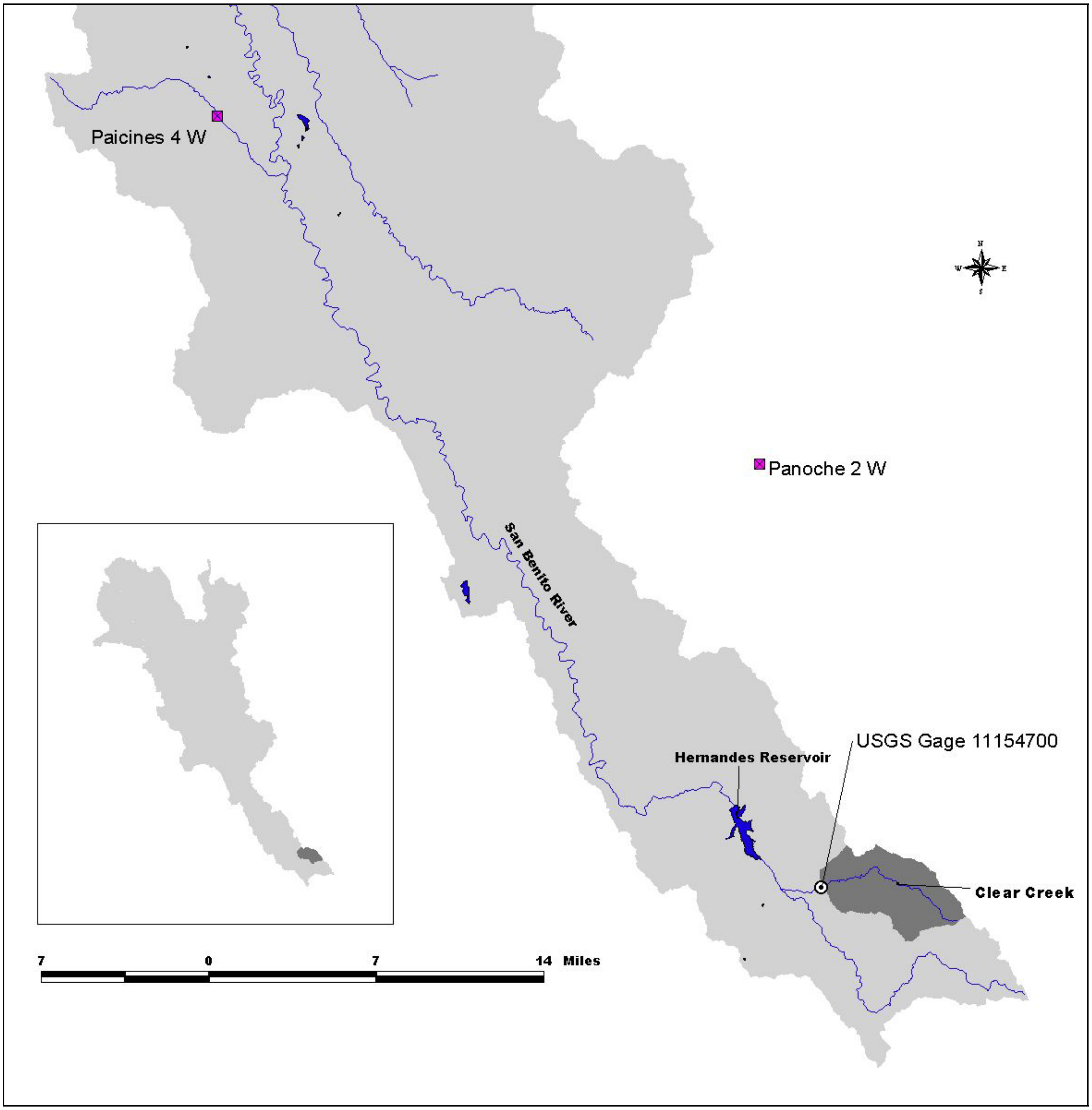



Figure 7-10. Location of Clear Creek watershed.

### 7.2.1 Hydrology Calibration (Clear Creek)

Figures 7-11 through 7-16 present daily, monthly and yearly calibration results for the Clear Creek model hydrology. Hydrology was calibrated for the period October 1, 1994 to October 1, 1995 and validated for the period October 1, 2000 to September 30, 2001.

Daily flow simulations match well with observed flows with respect to time, peaks, and duration.

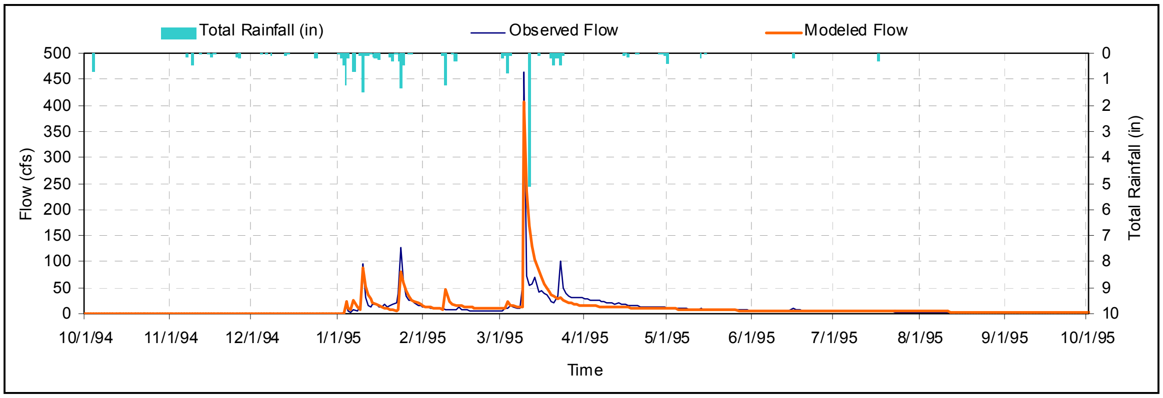



Figure 7-11. Hydrology calibration, Clear Creek, 10/1/1994 – 10/1/1995.

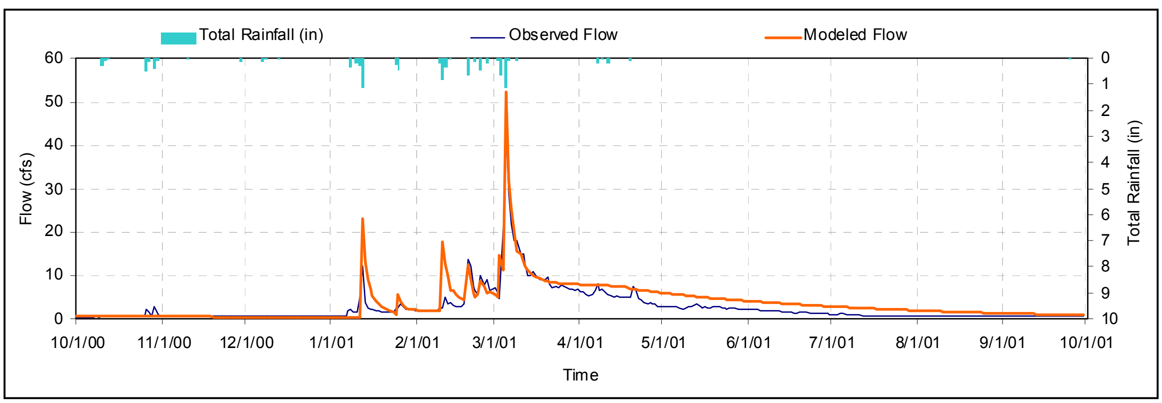
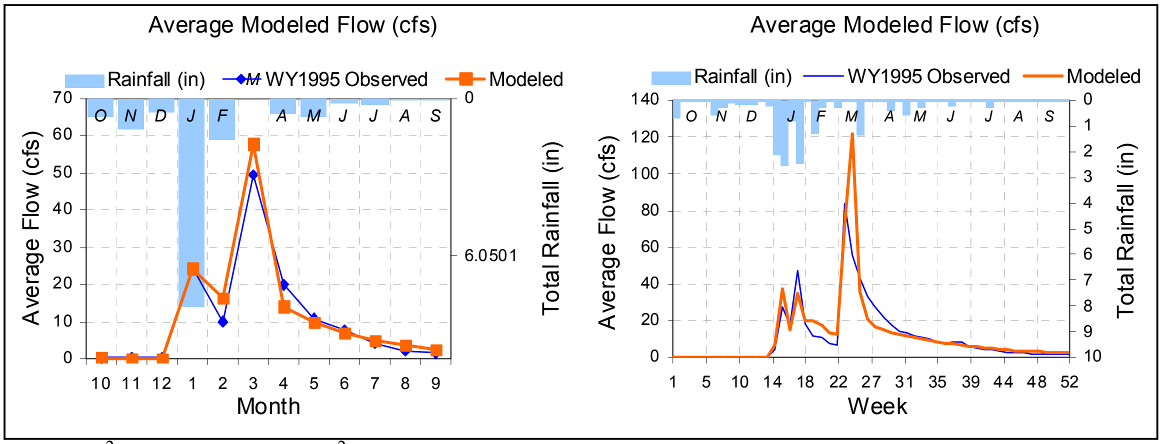



Figure 7-12. Hydrology validation, Clear Creek, 10/1/2000 – 9/30/2001.

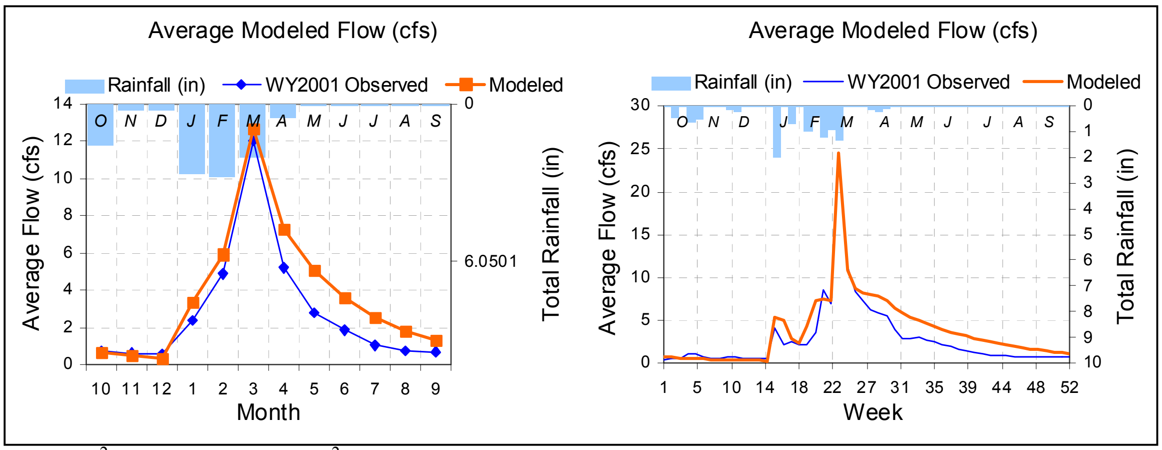
Monthly and weekly analyses also show strong correlations between modeled and observed values. Figures 7-13 and 7-14 show the same analysis for two years, WY 1995 and WY 2001.[9]

9 WY 1995: monthly $R^2 = 0.9609$; weekly $R^2 = 0.7416$.
WY 2001: monthly $R^2 = 0.9458$; weekly $R^2 = 0.9309$




Monthly $R^2$ = 0.9609; Weekly $R^2$ = 0.7416

Figure 7-13. Clear Creek monthly and weekly flow calibration analysis, WY 1995.




Monthly $R^2$ = 0.9458; Weekly $R^2$ = 0.9309

Figure 7-14. Clear Creek monthly and weekly flow calibration analysis, WY 2001.

To further validate calibration, a continuous simulation for the period from 1994 to 2001 was run. Monthly results from this simulation are shown in Figure 7-15.

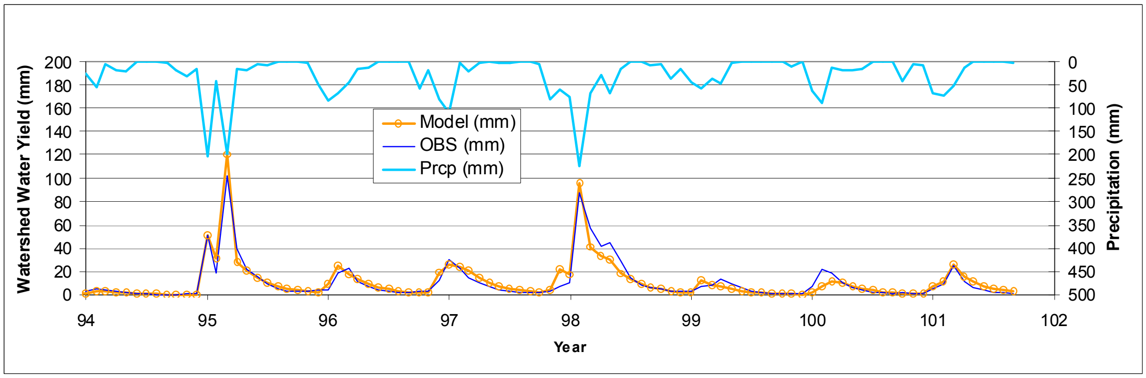



Figure 7-15. Clear Creek hydrology validation, monthly results, 1994--2001.

Figure 7-16 compares model results to USGS flow estimations in mean monthly water yield for the period 1993--2001).

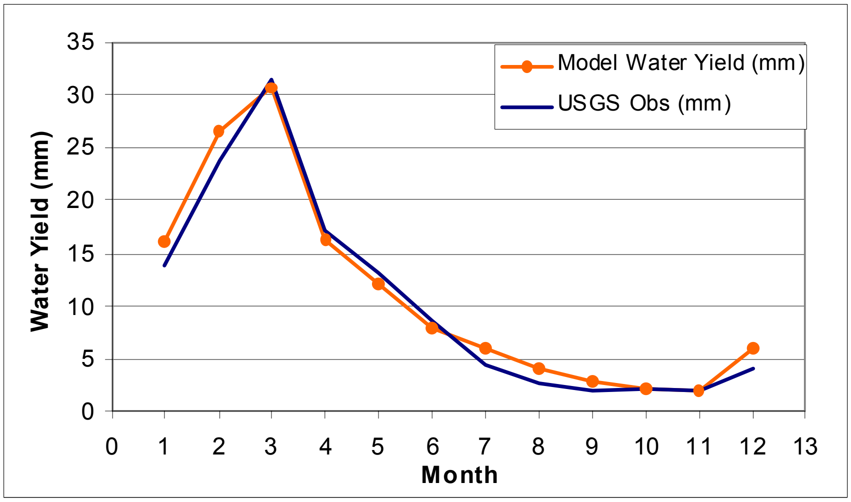



Figure 7-16. Clear Creek mean monthly water yields (modeled vs. observed, 1993--2001).

### *7.2.2 Water Quality Calibration (Clear Creek)*

Limited flow and suspended sediment data are available for the USGS gage on Clear Creek (see Table 3-4)[10]. Using the U.S. Army Corps of Engineers FLUX program, these data were used to estimate the sediment load in Clear Creek (Walker 1999). Based on FLUX regression methods, average annual sediment loading in Clear Creek ranges from 2,033 to 4,209 metric tons per year or 159 to 329 U.S. tons per square mile per year. The lower estimation was consistent with the estimated annual yield given by PTI Environmental Services in a 1993 report, *Erosion and*

10 Regression of instantaneous flow and SSC yields an $R^2 = 0.5524$.

*Sedimentation in the Clear Creek Watershed*. PTI estimated the average annual *undisturbed* sediment yield in Clear Creek to be approximately 2,025 US tons per year (166 tons per square mile per year).

The sediment load for the Clear Creek SWAT model was calibrated to the highest estimation of the FLUX program because of the extensive unpaved roads for off-highway vehicles and sparse vegetation cover in the study area. The calibrated annual average load was 4,357 metric tons per year (341 US tons per square mile per year). Figure 7-17 shows the annual variation in sediment loads and compares simulated annual loads with those estimated using the FLUX program.

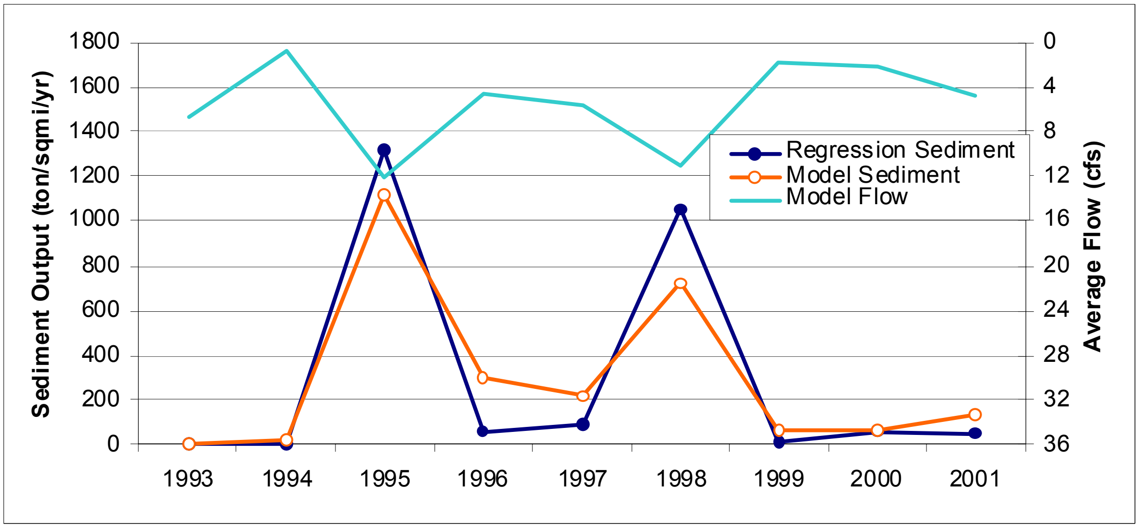



Figure 7-17. Modeled vs. FLUX generated annual sediment load, Clear Creek.

The simulated daily sediment concentration is shown in Figure 7-18. Concentration ranges from 1 to 10,500 mg/L for flows ranging from 0 to 406 cfs. Most of the sediment data are below 5,000 mg/L, overlapping with the limited USGS observations (suspended sediment ranges from 0 to 3,720 mg/L for flows from 0.2 to 85 cfs).

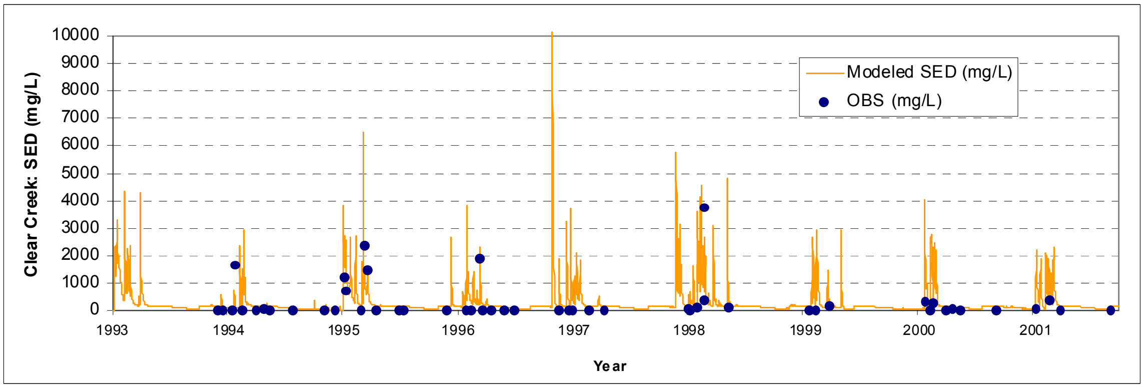



Figure 7-18. Simulated sediment concentrations and observed data, Clear Creek.

## 7.3 Pajaro River at Chittenden Calibration

The Pajaro River at Chittenden (Figure 7-19) drains most of the watershed (94 per cent of the area). The area of the Pajaro River watershed at Chittenden is about 1186.4 square miles. Land use distribution is approximately 59 per cent rangeland, 24 per cent forest, and 11 per cent pasture/crop land.

Weather data used to drive the model for calibrating the model at Chittenden were taken from CA 4025 Hollister 2 (temperature and precipitation); CA 46610 Paicines 4W (temperature); CA46675 Panoche 2W (precipitation); and 7946 Santa Maria WSO (solar radiation).

The proportion of base-flow to surface runoff was calculated for USGS gage 11159000 at Chittenden, using the SWAT base-flow filter program and USGS flow data from 10/1/1993 to 9/30/2001. Base-flow represents approximately 36 per cent to 54 per cent of the total annual flow. Water yield, total annual flow generated by precipitation, is approximately 15 per cent of annual precipitation based on observation data.

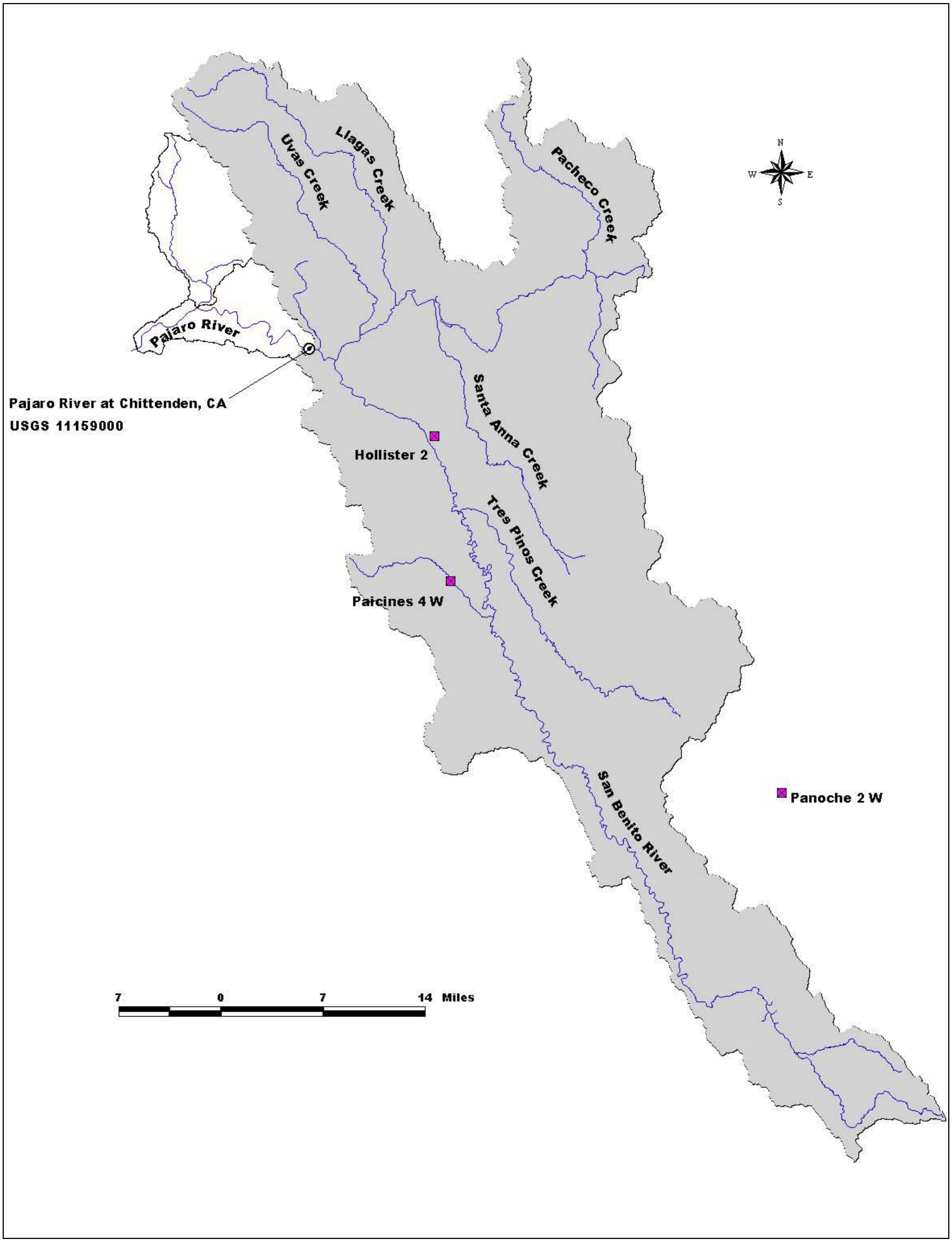



Figure 7-19. Pajaro River at Chittenden (USGS gage 11159000).

### *7.3.1 Hydrology Calibration (Chittenden)*

Monthly average discharge estimates from the model were compared to monitored gage data at station 11159000. Figure 7-20 shows daily simulation results for modeled vs. observed flows for the calibration period October 1, 1982, to October 1, 1983. The flow calibration was validated for the period October 1, 1994, to September 30, 1995 (Figure 7-21).

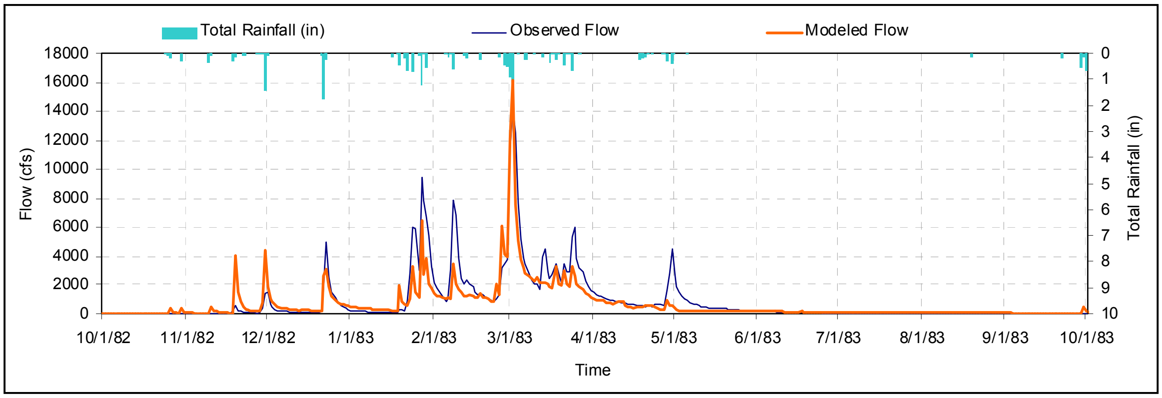



Figure 7-20. Hydrology calibration, Chittenden, 10/1/1982 to 10/1/1983.

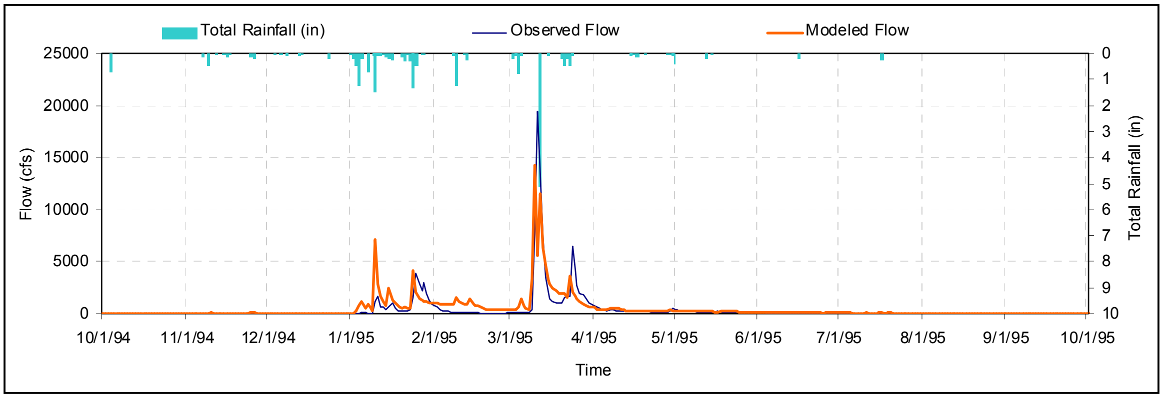
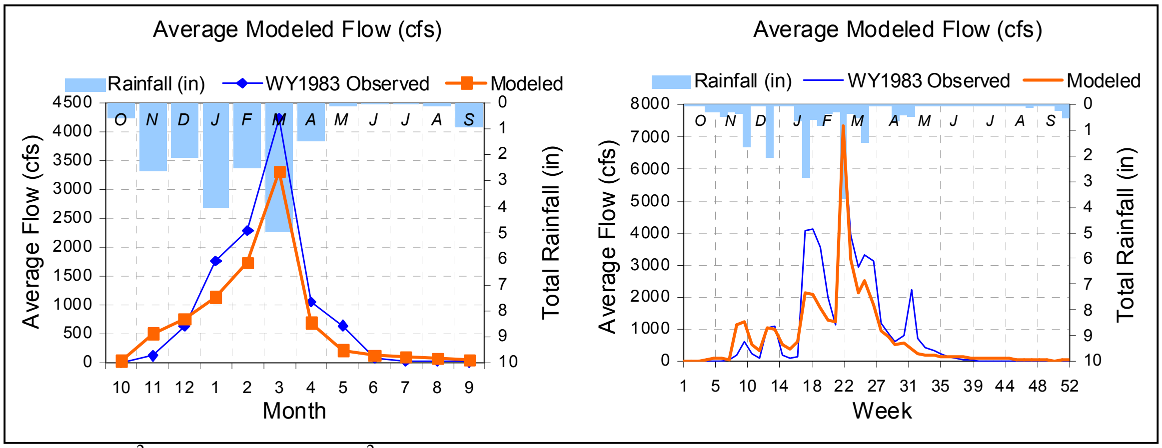


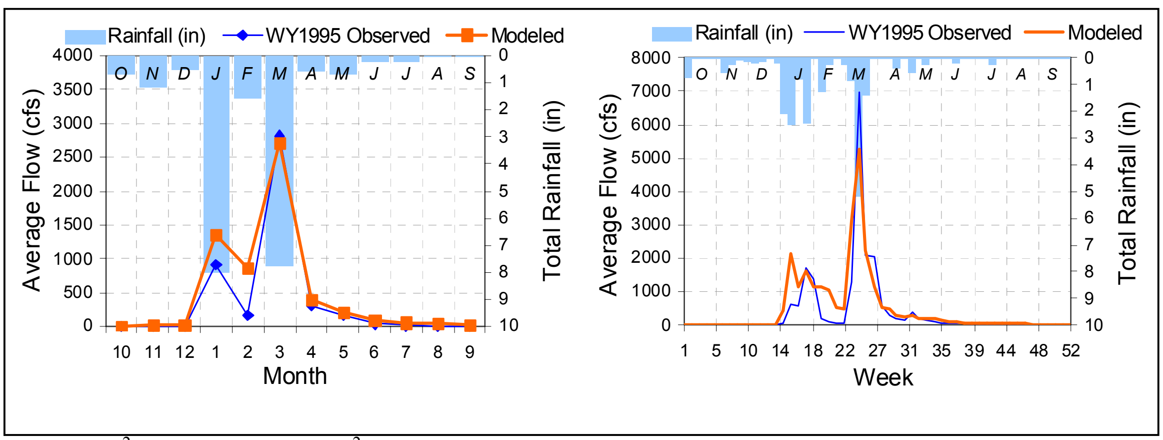

Figure 7-21. Hydrology validation, Chittenden, 10/1/1994 to 9/30/1995.

Monthly and weekly analyses show good correlation between the model prediction and USGS flow estimation. Figures 7-22 and 7-23 present results for WYs 1983 and 1995.




Monthly $R^2$ = 0.9634; Weekly $R^2$ = 0.8416

Figure 7-22. Chittenden monthly and weekly flow calibration analysis, WY 1983.




Monthly $R^2$ = 0.9235; Weekly $R^2$ = 0.8007

Figure 7-23. Chittenden monthly and weekly flow calibration analysis, WY 1995.

To further validate the calibration, a continuous simulation for the period 1994 to 2001 was run. Monthly results from this simulation are shown in Figure 7-24.

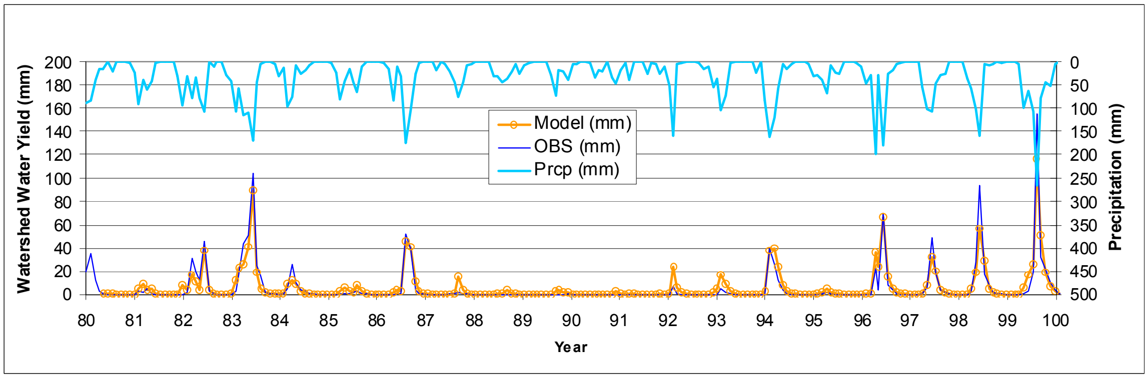



Figure 7-24. Chittenden hydrology validation, monthly results, 1994--2001.

Figure 7-25 compares model results for monthly mean modeled water yield to USGS observations for the period 1980--1999. Model predictions correlate strongly with observations ($R^2 = 0.985$).

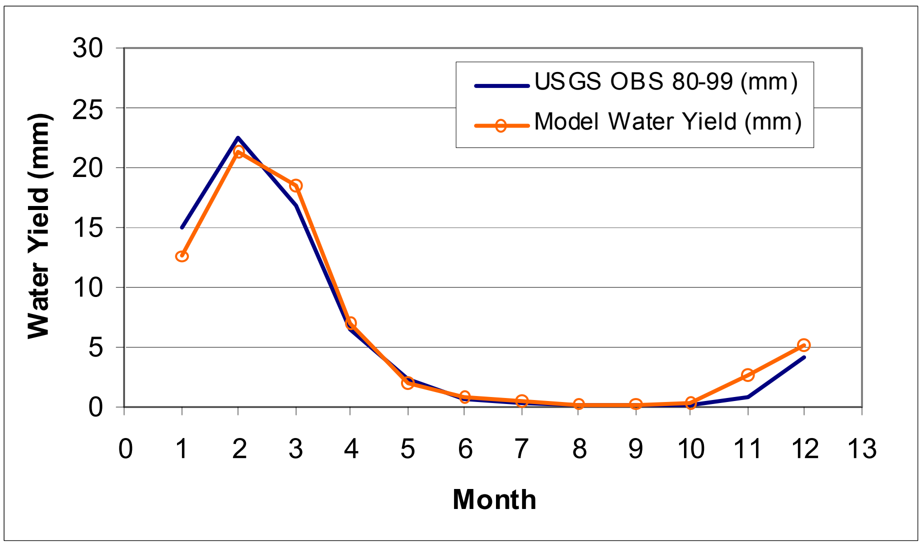



Figure 7-25. Chittenden mean monthly water yields (modeled vs. observed, 1980--1999).

### 7.3.2 Water Quality Calibration (Chittenden)

107 observations of flow and suspended sediment data are available for the USGS gage on the Pajaro River at Chittenden (see Table 3-4).[11] The apparent relationship between flow and sediment concentration is more similar to that at Clear Creek than that at Corralitos. At this location, the Pajaro River drains a large area, and one might expect the sediment/flow

11 Regression of instantaneous flow and SSC yields an $R^2 = 0.5408$

relationship to be affected by flood control structures and channelization, as well as irrigation and irrigation return flows.

Using the U.S. Army Corps of Engineers FLUX program, these data were used to estimate the annual sediment load. Based on Flux regression methods, average annual sediment loading at Chittenden ranges from 119,221 to 233,167 metric tons per year or 110 to 217 U.S. tons per square mile per year.

Phillip Williams and Associates (1996) estimated the sediment yield as 93 US tons per square mile per year for Pajaro River. Balance Hydrologics (1990) estimated 440 U.S. tons per square mile per year of sediment yield for the period of 1981-1986, a wet period. *Golder* (1997) estimated that sediment yield was 81 U.S. tons per square mile per year for the San Benito River. The FLUX estimation seems to be consistent with the range of above estimates.

The sediment load from SWAT model for the Pajaro River at Chittenden was calibrated to an annual average load of 151,580 metric ton per year or 141 US tons per square mile per year based on the FLUX-generated average annual loading estimate. Figure 7-26 shows the SWAT simulated annual sediment load and that estimated using the FLUX program. The total simulated sediment load from 1/1/1981 to 12/31/1999 is 2,273,706 metric tons, which is within the range of the estimates (1,788,312 to 3,497,507 metric tons) based on the USGS data and FLUX program.

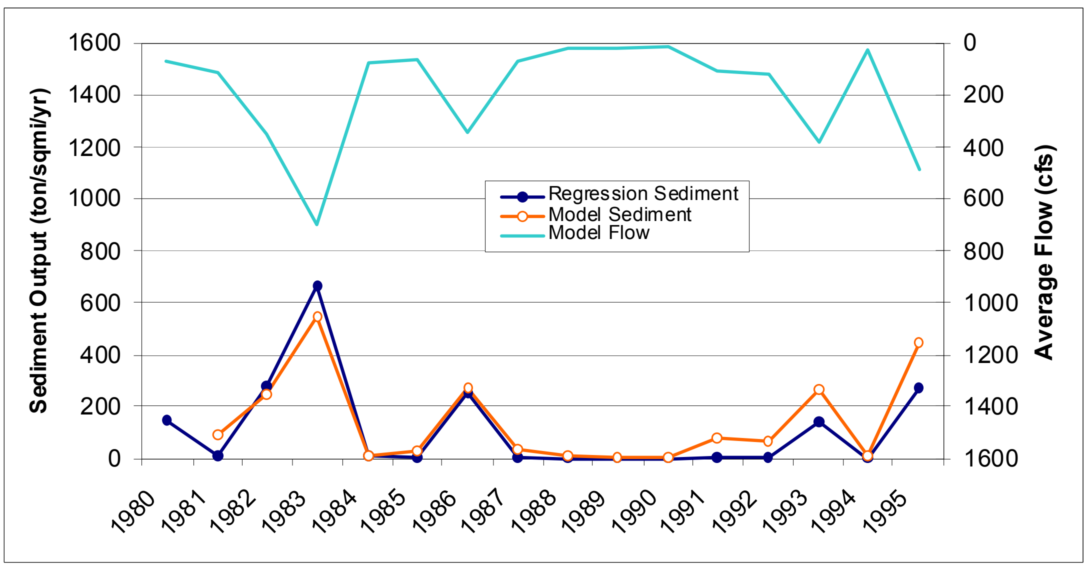



Figure 7-26. Modeled vs. FLUX-generated annual sediment load, Chittenden.

The simulated daily sediment concentration is shown in Figure 7-27. Modeled concentrations can be as high as 5,070 mg/L for flows up to 11,336 cfs (most of the sediment data are below 5,000 mg/L). This range overlaps with the 1980 to 1993 USGS and 1998 to 1999 CCAMP observations (suspended sediment ranges from 0 to 4,460 mg/L for limited observed flow ranges).

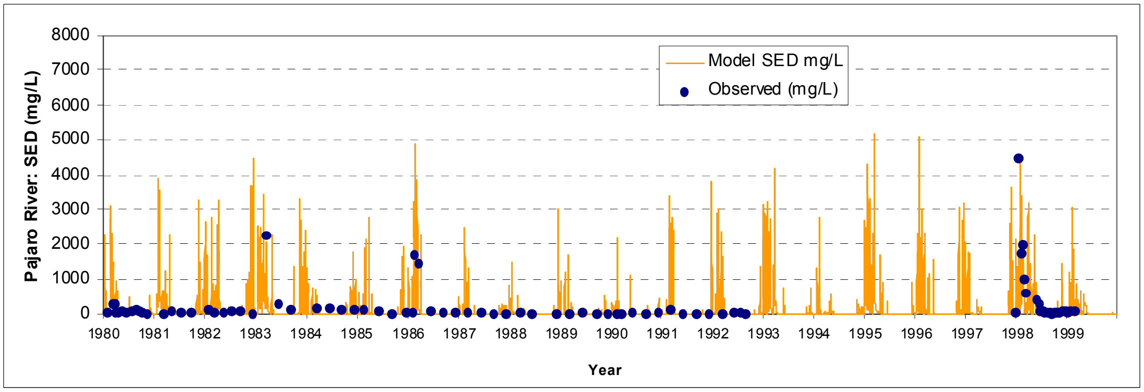



Figure 7-27. Simulated daily sediment concentrations and observations (USGS and CCAMP).

# 8.0 LOADING ESTIMATION AND TMDLS

The calibrated SWAT model was used to simulate flow and sediment in the Pajaro River watershed to estimate existing sediment loads for the period 1986 to 2000. A loading scenario reflective of reductions to anthropogenic sediment sources was developed and is presented as the TMDL for each subbasin.

## 8.1 Existing Loading

Existing conditions were estimated by simulating loading from current land uses and stream channel erosion. In subbasins 3, 15, and 20 (Rider Creek, Hollister Hills, and Clear Creek) road-related erosion was also simulated. From a long-term loading standpoint, stream channel erosion and deposition estimates are an important component of the sediment loading in the Pajaro River watershed. Channel erosion estimates are not presented for individual subbasins; however, they are accounted for in the total annual loading estimates. The loading analysis did not address the effects of channel modifications for flood control. The total estimated annual load for the Pajaro River watershed under existing conditions is 336,014 US tons. See Section 8.6 for subwatershed and subbasin estimates of existing annual loading by land use type.

## 8.2 Natural Loading

Two kinds of natural sediment loading occur in the Pajaro River watershed. Loading which originates from undisturbed, relatively vegetated areas, and loading which originates from steeper, geologically active, and less vegetated areas. Sediment loads from the former can be characterized as steady and small scale in nature compared to loads from the latter, which are generally much greater and sporadic.

For the Pajaro River watershed TMDL, forested, grassland, and shrubland areas are generally considered natural (see Table 6-1, page 59). These landuse types represent the first category of natural loading discussed above. Section 8.6 presents these loads as either 'Forest' or 'Range'. In predominantly forested or grassland areas where additional loading has been attributed to roads, road-related loading has been estimated separately.

The "ROCK" land use category in SWAT represents the latter category—those areas in the Pajaro River watershed that are distinguished by barren areas with sandy or rocky soil, and are subject to mass wasting and slumping. Loading from this category, labeled as "Barren" in Section 8.6, incorporates such phenomena as landslides.

## 8.3 Allocation Methodology

Although sediment loading in the Pajaro River watershed might be naturally high, increased concentrations associated with anthropogenic activities have been implicated in contributing to water quality degradation and habitat impairment. Therefore, it is these sources that are targeted for loading reductions. Generally, allocations and reductions were based on the land uses present in the subwatershed as represented by the MRLC land use coverage. In addition to existing land uses, road-related features are also significant sediment sources in the Pajaro watershed, depending on location. For specific areas in which roads are known to contribute to sediment loading, allocations and reductions were also made to roads (unpaved). The following paragraphs describe the general allocation strategies followed for specific subwatersheds in the Pajaro River watershed.

### 8.3.1 San Benito (modeled subbasins 15, 17, 20, and 21)

The San Benito River watershed is the largest in the Pajaro drainage. In the upper portions of the watershed (subbasins 20 and 21), ground cover consists of dry land pasture and forest/brush complex. Lower reaches have been historically mined for sand and gravel transported from upper reaches. This appears to be one of the major sediment influences in the San Benito, affecting stream hydraulics, flow velocities, and sediment carrying capacity. Landslide features are present in central and downstream portions. Golder Associates identified numerous landslides in the watershed during a 1997 survey, the largest of which is in the upper portions of subbasin 15. Most of the cultivated agriculture in this watershed is in subbasin 15; a smaller amount is in subbasin 17. Streambank erosion is probably a significant contributor. Cattle impacts in this area are limited. A small portion of the Hollister urban boundary lies within subbasin 15. Land use distribution in the San Benito watershed is predominantly grassland/herbaceous (34 percent), forest (25 percent), shrubland (28 percent), pasture/hay (5 percent), bare rock (3 percent), and cultivated agriculture (2.5 percent). Other minor land uses comprise the remaining portion.

**Allocation Strategy:**
Existing and allowable loads were identified. Because of the lack of specific data on most major sources in this watershed, it was deemed appropriate to identify the overall reduction necessary to meet sediment targets in this watershed regardless of specific land uses, with the exception of cultivated agriculture. This exception was made because enough information regarding cultivated agriculture in the area is available to reasonably identify that loading and necessary reductions. As a result, a portion of the load allocation was assigned specifically to cultivated agriculture and necessary reductions were specified for cultivated agriculture; the remaining portion of the load allocation was lumped into a gross loading category that includes all other land use sources in the watershed. The Regional Board is to determine the necessary reductions from the individual land use categories at a later point, after additional source-specific information can be collected. Loadings from urban land uses (531 acres) lying within the Hollister urban boundary (in subbasin 15) were assigned a Waste Load Allocation (WLA) (see Table 8-2).

Existing loading from off-highway vehicle recreation areas in the Clear Creek watershed (subbasin 20) was identified. Sediment from the Clear Creek area is captured and retained in Hernandez Reservoir and thus does not contribute to loads at the mouth of the San Benito; however, loads from vehicle trails in the watershed have been identified as excessive. Likewise, loading from road features in the Hollister Hills recreation area (in subbasin 15 on Bird Creek) was identified. Loads from unpaved roads were reduced by 100 percent to zero tons per year in this TMDL scenario, since these sources are considered entirely controllable through best management practices.

### 8.3.2 Tres Pinos (modeled subbasins 16, 18, and 19)

The Tres Pinos watershed is steep, faulted, naturally highly erodable, and subject to substantial mass wasting events. Many landslide features are present, especially in the central and lower portions. Ground cover is primarily dry land pasture. The land use in the upper portions is mainly livestock grazing. Agriculture is present along the river valley, and there are orchards and pasture/hay areas along the stream in lower portions of subbasin 16. Ayers Associates (1999) estimated that the Tres Pinos has higher annual sediment loading rates than the San Benito.

**Allocation Strategy:**
The allocation strategy for the Tres Pinos Creek watershed was the same as that for the San Benito. Allocations were specified for cultivated agriculture and gross loadings. Loadings from urban land uses (4 acres) lying within the Hollister urban boundary (in subbasin 16) were assigned a WLA (see Table 8-3).

### 8.3.3 Corralitos/Salsipuedes Creek (modeled subbasins 3, 4, and 7)

The Corralitos/Salsipuedes Creek watershed is in the northwestern portions of the Pajaro River watershed, near the outlet. Approximately 54 square miles, the watershed also contains Rider Creek. (To address the specific section 303(d) listing for Rider Creek, a smaller SWAT project was created to minimize computation time.) Land use distribution is predominantly forest (54 percent), agriculture (11 percent), grassland (27 percent), and developed (7 percent). Significant portions of the city of Watsonville lie within the watershed boundary.

**Allocation Strategy:**
Allocations and reductions to sediment sources in the Corralitos/Salsipuedes Creek watershed were based on MRLC land uses. Priority reductions were made to cultivated agriculture. Loadings from urban land uses (233 acres in subbasin 3; 333 acres in subbasin 4; and 871 acres in subbasin 7) lying within the Watsonville urban boundary were assigned a WLA (see Table 8-4).

### 8.3.4 Rider Creek

Rider Creek, a tributary to Corralitos Creek, is in the coastal fog belt, approximately 4 miles from the epicenter of the 1989 Loma Prieta earthquake. The watershed is relatively small, steep, and geologically active, and it receives about 35 inches of rainfall per year. Land use distribution is predominantly forested (90 per cent) and grassland/herbaceous (10 per cent ). Small amounts of low-intensity residential and some apple orchard development are mainly situated along the watershed divides and away from the inner creek canyon. Rider Creek is specifically included on the section 303(d) list. Sand-sized sediment is exported to Corralitos Creek during the summer months. These sediments, during summer base-flow conditions, fall out of suspension and blanket the streambed of Corralitos Creek from the mouth of Rider Creek down, adversely affecting steelhead-rearing habitat.

Before the Rider Creek watershed was settled, it was heavily forested with old growth coastal redwood, and with tanbark oak and coast live oak on dry sunny sites. Old growth trees were logged in the late 1800s, using steep, narrow skid roads to the creek. Logging activities were resumed over the past few decades, using "new steep access roads cut to felling sites from existing relatively high standard, low gradient dirt roads" (WRC Environmental 1991).

The abundant sediment production in the watershed is attributed to the watershed's natural conditions (land uplift, stream channel downcutting, and enlargement of the inner canyon), which are compounded by road-related features (road gullies, slumping from road cuts, and maintenance sidecasts[12]). Although *natural* conditions in the watershed contribute to the high sediment loads, a portion of the road-related loading is deemed controllable.

**Allocation Strategy**:
Allocations and reductions to sediment sources in the Rider Creek watershed were based on MRLC land uses and road-related features. Allocations were made to all existing land uses. Priority reductions were made to road-related features. Contributions from road features were estimated based on the US Census Bureau's Tiger coverage (Figure 8-1), which gives an approximation of the roads in this area (see Table 8-5).

12 Refers to the placement of slide-generated sediment materials alongside roads.

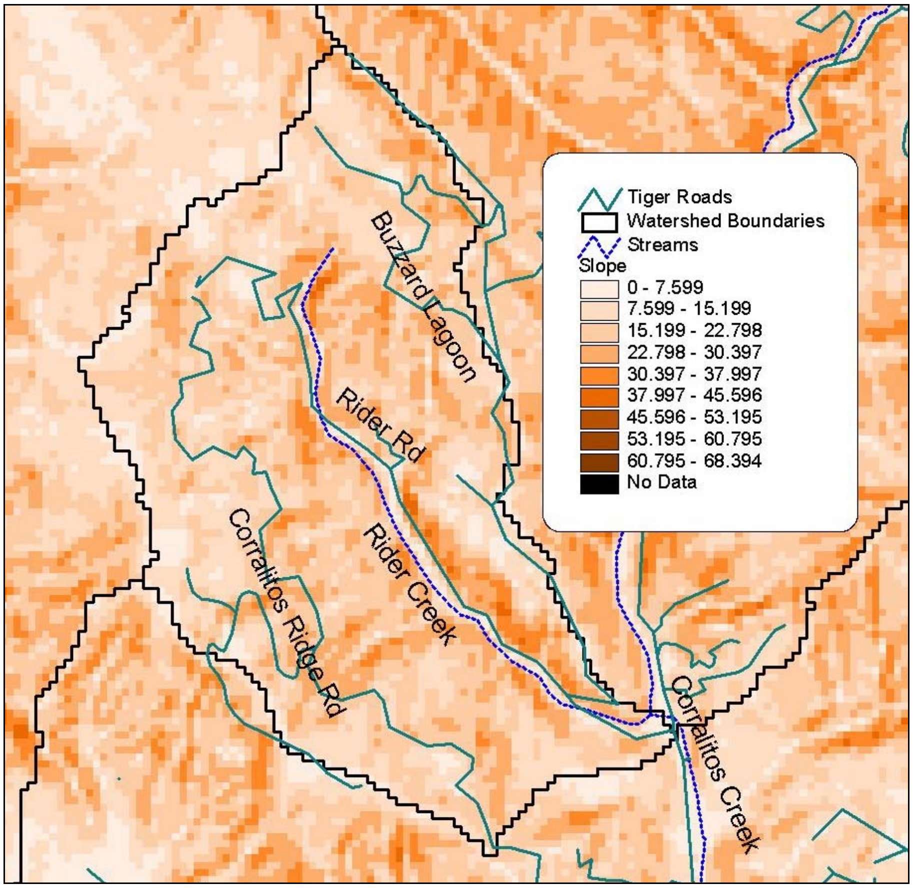



Figure 8-1. Rider Creek roads.

Given that sediment from Rider Creek tends to inundate the streambed of Corralitos Creek during summer base-flow conditions (when flow in Corralitos Creek at the Rider Creek confluence is less than about 10 cfs), sediment concentration reductions to sources in Rider Creek might not necessarily alleviate the problem in Corralitos Creek. It is assumed however, that controlling sediment loading in this watershed, as in the rest of the Pajaro watershed, should have some beneficial impact on the sediment impairment. Due to the unique set of critical conditions (low flow) in his subwatershed, further assessment should be made regarding application of additional targets. Particularly, these targets should be substrate targets such as particle size distribution for spawning gravels or percent fines.

### *8.3.5 Llagas Creek (modeled subbasins 5 and 23)*

Llagas Creek ranges in elevation from 3,562 feet near Loma Prieta Peak in the northwest to 140 feet at the confluence with the Pajaro River. It is listed as a 303(d) waterbody beginning below the Chesbro Reservoir. The Llagas Creek watershed is represented in the Pajaro River watershed SWAT model by subbasins 5 and 23. The portion of the creek in subbasin 23 is not included in the listing because it drains areas above the reservoir. The urbanized areas of Morgan Hill and Gilroy are in this watershed.

Land use distribution in subbasin 5 of Llagas Creek is predominantly urban (13 per cent), forested/shrub (10 per cent), orchard/vineyard (32 per cent), grassland/herbaceous (32 per cent), pasture/hay (5 per cent) and rowcrops (6 per cent) as well as a small portion of other minor land use categories. Most agricultural lands in the Llagas Creek watershed are separated from the creek by levees (SJSU 1994). Potential sediment-related issues in the Llagas Creek watershed include summer irrigation, winter storm runoff, and tillage practices.

**Allocation Strategy:**
The allocation strategy in Llagas Creek watershed was based on the MRLC land use coverage. Allocations were made to all existing land uses. Priority reductions were made to cultivated agriculture, and pasture/hay areas. Loadings from urban land uses (6,104 acres) lying within the Morgan Hill--Gilroy urban boundary (in subbasin 5) were assigned a WLA (see Table 8-6).

### *8.3.6 Uvas Creek (modeled subbasins 11 and 22)*

This watershed is not included on the section 303(d) list of impaired waterbodies. Estimated sediment yields in this watershed are low relative to other watersheds in the Pajaro drainage. The estimated yield for Uvas Creek above Uvas Reservoir is 301 tons per square mile per year (ASE 1999). Outlying portions of the urbanized area of Gilroy lie on the eastern ridge of the Uvas Creek watershed. Land use distribution includes forested/shrub (65 per cent), grassland/herbaceous (24 per cent), orchard/vineyard (4 per cent), pasture/hay (3 per cent), and row crops (1 per cent).

**Allocation Strategy:**
The allocation strategy for Uvas Creek watershed was based on the MRLC land use coverage. Allocations were made to all existing land uses. Priority reductions were made to cultivated agriculture, and pasture/hay areas. Loadings from urban land uses (279 acres) lying within the Morgan Hill--Gilroy urban boundary (in subbasin 11) were assigned a WLA (see Table 8-7).

### *8.3.7 Upper Pajaro River (modeled subbasins 1, 2, 9, and 10)*

For modeling purposes, the Upper Pajaro River is considered to include Pacheco Creek (including the North and South Forks) and Santa Ana Creek. Significant pasture/hay lands (21 per cent) as well as cultivated agricultural lands (8 per cent) are located in subbasin 9, Santa Ana Creek. Most of the urbanized area of Hollister lies within the boundaries of subbasin 9; however, urban land uses make up only 3.5 per cent of the watershed area. Agricultural areas also lie along the sides of Pacheco Creek in the lower portions of subbasin 10 (7 per cent cultivated, 6 per cent pasture/hay). Remaining areas in the three Upper Pajaro watersheds are largely forest, shrub, and grassland. Though numerous Pajaro River watershed reports are available, none provide estimates of sediment loading specific to the watersheds of the Upper Pajaro.

Three important physical features affecting sediment transport in the Upper Pajaro are Pacheco Lake, San Felipe Lake (also known as Upper Soap Lake) and Soap Lake. San Felipe Lake is a permanent body of water. It represents the headwaters of the Pajaro River and is fed by Tequisquita Slough and Pacheco Creek. Soap Lake (or Lower Soap Lake) is an area of low elevation that fills with water during times of heavy rainfall due to flow backups at the narrow Chittenden Gap. Pacheco Lake and San Felipe Lake (as well as Soap Lake at times of extreme flooding) intercept sediment from the streams of the Upper Pajaro before it can enter the Lower Pajaro (RMC 2002). Figure 8-2 shows San Felipe Lake and provides an approximate depiction of the location of Soap Lake. The Pajaro River Watershed SWAT model simulates both Pacheco and San Felipe Lakes and the sediment attenuation associated with them. Sediment attenuation by Soap Lake during extreme flood situations is not represented.

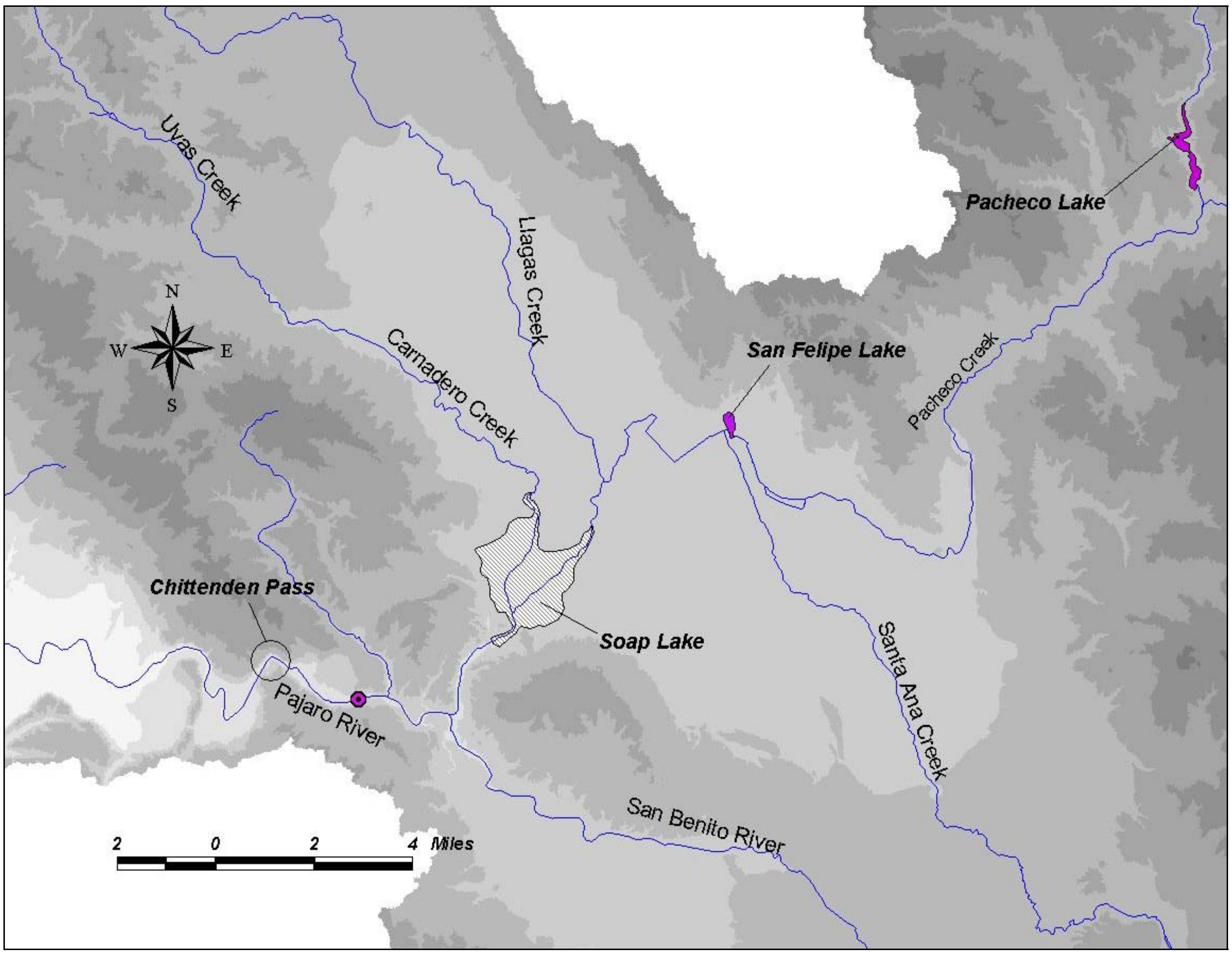



Figure 8-2. Soap Lake, San Felipe Lake and Pacheco Lake.

**Allocation Strategy:**

The allocation strategy for the Upper Pajaro watershed was based on the MRLC land use coverage. Allocations were given to all existing land uses. Priority reductions were made to cultivated agriculture, and pasture/hay areas. Loadings from urban land uses (1,640 acres) lying within the Hollister urban boundary (in subbasin 9) were assigned a WLA. To differentiate between areas upstream and downstream of San Felipe Lake, model outputs were analyzed at subbasin 9 and at subbasin 10 (see Tables 8-8 and 8-9).

### 8.3.8 Lower Pajaro River (modeled subbasins 6, 8, 12, 13, 14, and 24)

The Lower Pajaro represents the most downstream portion of the Pajaro drainage. Most sediment coming through the Lower Pajaro is believed to originate locally and from the San Benito and Corralitos/Salsipuedes watersheds as opposed to the Upper Pajaro (RMC 2002). Riverbanks along Chittenden Pass are unstable in numerous locations, making streambank erosion a likely significant source of sediment in this area.

Levees completed in the late 1940s for flood control contribute to channel downcutting. The resulting deepening of the channel has effectively cut the river off from its natural floodplain, reducing the capacity of the Pajaro floodplain for storing floodwaters and sediment during extreme storm events. Land use distribution in the Lower Pajaro includes cultivated agriculture (28 per cent), grassland/herbaceous (25 per cent), pasture/hay (21 per cent), forest (11 per cent), shrub (9 per cent), and urban (3 per cent). Portions of the Watsonville urban area lie within the boundaries of subbasins 8 and 13.

**Allocation Strategy:**
The allocation strategy for the Lower Pajaro watershed was based on the MRLC land use coverage. Allocations were given to all existing land uses. Priority reductions were made to cultivated agriculture, barren lands, and pasture/hay areas. Loadings from urban land uses (151 and 313 acres) lying within the Watsonville urban boundary (in subbasins 8 and 13) were assigned a WLA (see Table 8-10).

## 8.4 Margin of Safety

There are two methods for incorporating the MOS (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
- Explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations.

For the Pajaro River watershed sediment TMDL, an implicit MOS was incorporated in several ways. The use of a multiple-year simulation period (1986 to 2000) enabled the consideration of multiple hydrologic conditions. Throughout the TMDL development process, conservative assumptions were made. For example, sediment concentrations associated with the selected target may be conservative with respect to the high loading scenarios that occur naturally in the Pajaro River watershed. The exposure category methodology also incorporates a range (rather than a finite value) of concentrations and durations of exposure associated with a given response level (refer to Table 2-5, page 15). The selection of the range of concentration values as TMDL targets at multiple subwatershed locations rather than a single target represents a conservative development approach. Targets were selected to be protective of the most sensitive of beneficial uses (cold water fish) and are thus more rigorous than they would be if another beneficial use were being protected.

## 8.5 Seasonality and Critical Conditions

Sediment concentration data for the Pajaro River watershed show that the largest loading of sediment to the watershed typically occurs during the winter months at high-flow periods. Sediment loading in some portions of the watershed is also extremely sporadic in nature. For example, over a 10-year period, a disproportionately large amount of loading, 80 percent, might be delivered in one wet year, with 20 percent delivered over the course of the remaining dry years. Such disproportionate loading is determined by many factors, including topography, land use, geology, and soils. The relative unpredictability of loading especially in geologically active portions of the watershed, adds to modeling uncertainty. To ensure that the model would simulate the widest possible range of loading scenarios, a long-term simulation period covering a variety of hydrologic and rainfall conditions was used. (By calibrating the model to observations over long periods, it is assumed that such variability is captured.) By using continuous-flow simulation (estimating flow over a period of several years), seasonal hydrologic and source loading was inherently considered.

## 8.6 TMDL

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is represented by the equation

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards. In the case of the Pajaro River watershed, applicable water quality objectives are narrative and relate to aquatic life habitat. In TMDL development, allowable loadings from pollutant sources that cumulatively amount to no more than the TMDL must be established; this provides the basis for establishing water quality-based controls. TMDLs may be expressed on a mass loading basis (e.g., pounds of sediment per year) or as a concentration, in accordance with 40 CFR 130.2(l).

The TMDL represents reductions to anthropogenic sources (i.e., agriculture-related sediment is deemed anthropogenic, landslide generated sediment is not). The anthropogenic sources were assigned erosion parameters typically associated with range land; this is reflective of the relatively low sediment loading characteristics of range land. Road-related sediment loading was set to zero, and stream channel erosion was set to 20 percent of the existing level. Even under natural conditions, some channel erosion is expected to occur. The total load estimated for this scenario is 199,151 tons per year, while the total load estimated under the existing condition is 336,014 tons per year. Table 8-1 details model setup differences between the two loading scenarios. Figure 8-3 shows the difference in land use loading rates between each scenario. The major difference in loading between the two scenarios occurs in the anthropogenically affected landuses including agriculture (small grains, row crops, fallow, orchards, pasture), and mining.

Table 8-1. Model Setup for the Existing and TMDL Loading Scenarios

| Conditions | Existing | TMDL |
|---|---|---|
| Road | Road erosion in basins 3, 15, 20 | 100% road erosion controlled |
| Channel | Channel erosion | 80% channel erosion controlled |
| Runoff | Current runoff | No significant change |
| Erosion | Sediment loading rates are significantly high for cropland, fallow field (bare soil), mine sites, orchards, and pastureland. A high loading rate from the barren (ROCK) area (1.6% of the watershed) represents loading from natural disturbances such as landslides and fires. | Changed MUSLE C and P coefficients so that sediment loading rates decreased: 80% decrease in cropland, 80% decrease in fallow field, 80 % decrease in mine sites, 60% decrease in orchards, 60% decrease in pastureland, and 20% decrease in rangeland. After reduction, loading rates from the anthropogenic sources are comparable to that of rangeland. |

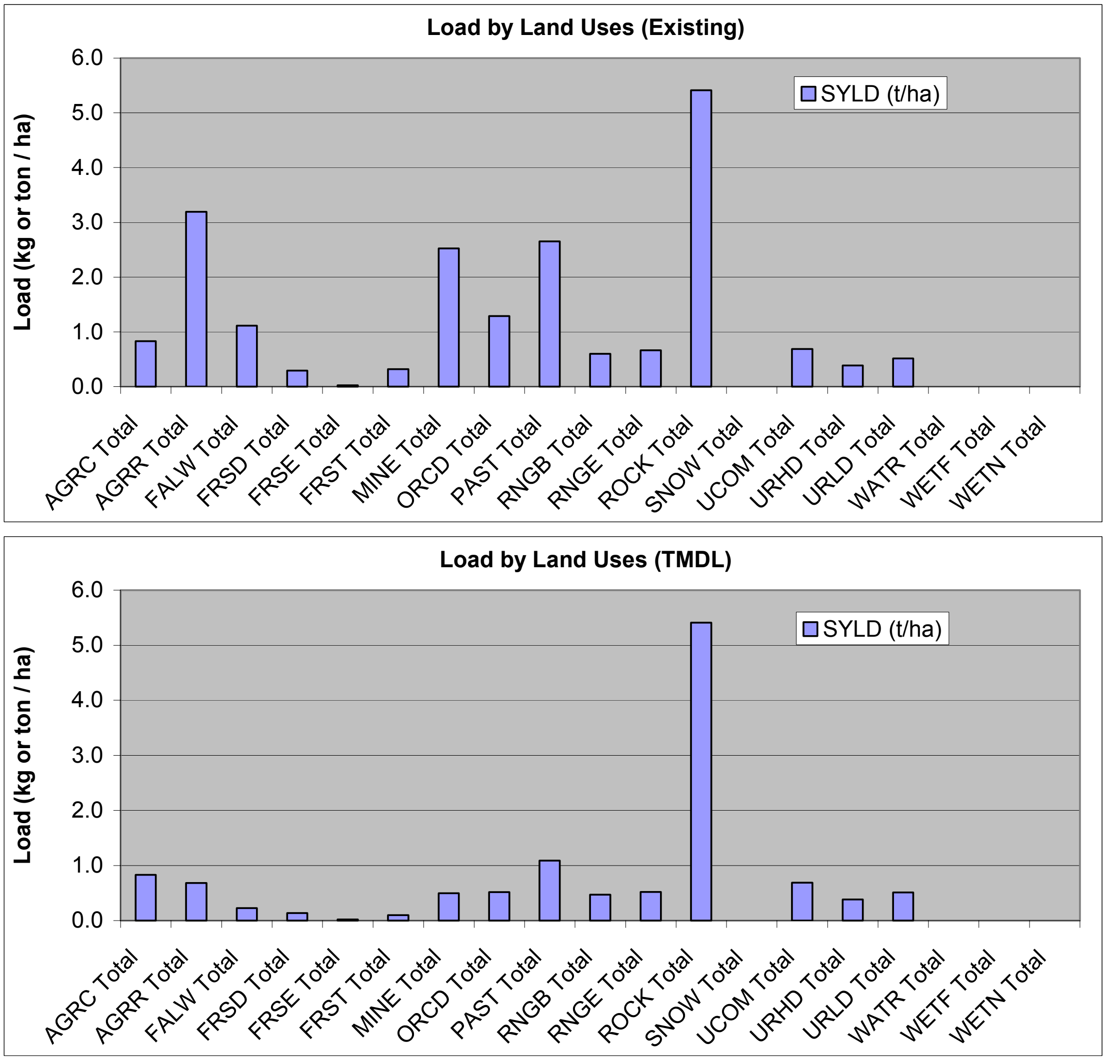



Figure 8-3. Annual land use loading rates for existing and TMDL scenarios

Landuse Key

| | | | |
|---|---|---|---|
| AGRC | Small Grains | RNGE | Grassland/Herbaceous |
| AGRR | Row Crops | ROCK | Barren/Bare Rock/Sand/Clay |
| FALW | Bare Soil (Fallow) | SNOW | Perennial Ice/Snow |
| FRSD | Deciduous Forest | UCOM | High Intensity Commercial/I |
| FRSE | Evergreen Forest | URHD | High Intensity Residential |
| FRST | Natural Forested Upland (no | URLD | Low Intensity Residential |
| MINE | Quarries/Strip Mines/Gravel | WATR | Water |
| ORCD | Planted Cultivated, Non-Natural Woody | WETF | Woody Wetlands |
| PAST | Pasture/Hay/Urban/Recreation Grasses | WETN | Emergent Herbaceous Wetland |
| RNGB | Shrubland | | |

Based on an interpretation of the model results for the TMDL and existing condition loadings, subbasin and landuse-specific annual loading rates were calculated. The majority of the sediment allocation is considered Load Allocation. Waste Load Allocations are specified for the subbasins containing urban landuses that lie within U.S. Census Bureau designated “urban boundaries”. (See Section 6.4.)

Tables 8-2 through 8-10 present the loads associated with the TMDL condition and Existing condition, as well as land use-specific loading rates by modeled subbasin. Results are presented for major subwatershed groupings. Load and Wasteload Allocations are identified, along with the percent reduction required to meet the TMDL conditions. (see Figure 6-1, page 56, for a map of the modeled subbasins.)

Table 8-2. TMDLs for San Benito River Subwatershed

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load 1 | Existing Sediment Load (t2) | TMDL Sediment Load (t2) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | Unpaved Road | 0.96 | 2.48 | 559 | - | 0% | 535 | - | 100% | - | 0 |
| | Crop | 4.73 | 12.25 | 636 | 130 | 7% | 3,011 | 616 | 80% | 616 | 0 |
| | Urban | 2.55 | 6.61 | 120 | 120 | 4% | 306 | 306 | 0% | 207 | 100 |
| | Gross | 78.84 | 204.18 | 199 | 96 | 89% | 15,674 | 7,605 | 51% | 7,605 | 0 |
| | *Subtotal* | *87.08* | *225.53* | *224* | *98* | *100%* | *19,526* | *8,527* | *56%* | *8,527* | *100* |
| 17 | Crop | 3.88 | 10.05 | 1,212 | 273 | 10% | 4,703 | 1,059 | 77% | 1,059 | 0 |
| | Gross | 98.36 | 254.75 | 166 | 101 | 90% | 16,343 | 9,921 | 39% | 9,921 | 0 |
| | *Subtotal* | *102.24* | *264.79* | *206* | *107* | *100%* | *21,046* | *10,980* | *48%* | *10,980* | *0* |
| 21 | Crop | 0.30 | 0.77 | 1,094 | 259 | 1% | 327 | 77 | 76% | 77 | 0 |
| | Gross | 163.16 | 422.58 | 82 | 62 | 99% | 13,427 | 10,042 | 25% | 10,042 | 0 |
| | *Subtotal* | *163.46* | *423.35* | *84* | *62* | *100%* | *13,754* | *10,119* | *26%* | *10,119* | *0* |
| 20 | Unpaved Road | 0.60 | 1.56 | 18,700 | - | 0% | 11,264 | - | 100% | - | 0 |
| | Crop | 0.02 | 0.04 | 662 | 142 | 0% | 10 | 2 | 78% | 2 | 0 |
| | Gross | 85.44 | 221.29 | 256 | 118 | 100% | 21,851 | 10,051 | 54% | 10,051 | 0 |
| | *Subtotal* | *86.06* | *222.89* | *385* | *117* | *100%* | *33,125* | *10,053* | *70%* | *10,053* | *0* |
| TOTAL | Unpaved Road | 1.56 | 4.04 | 7,564 | - | 0% | 11,799 | - | 100% | | |
| | Crop | 8.92 | 23.11 | 902 | 197 | 4% | 8,051 | 1,754 | 78% | | |
| | Urban | 2.55 | 6.61 | 120 | 120 | 1% | 306 | 306 | 0% | | |
| | Gross | 425.79 | 1102.79 | 158 | 88 | 95% | 67,294 | 37,618 | 44% | | |
| | ***TOTAL*** | ***438.83*** | ***1136.56*** | ***199*** | ***90*** | ***100%*** | ***87,451*** | ***39,679*** | ***55%*** | | |

[1]: based on existing load
[2]: metric tonnes

Table 8-3. TMDLs for Tres Pinos Creek Subwatershed

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load (t[2]) | TMDL Sediment Load (t[2]) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | Crop | 0.8 | 2.2 | 638 | 154 | 6% | 537 | 130 | 76% | 130 | 0 |
| | Urban | 0.2 | 0.6 | 106 | 106 | 1% | 25 | 25 | 0% | 23 | 1.06 |
| | Gross | 27.3 | 70.7 | 149 | 77 | 93% | 4,073 | 2,111 | 48% | 2,111 | 0 |
| | *Subtotal* | *28.4* | *73.5* | *894* | *338* | *100%* | *4,635* | *2,266* | *51%* | *2,265* | *1* |
| 18 | Crop | 0.1 | 0.2 | 3,655 | 920 | 0% | 251 | 63 | 75% | 63 | 0 |
| | Gross | 80.3 | 207.9 | 324 | 258 | 100% | 25,977 | 20,712 | 20% | 20,712 | 0 |
| | *Subtotal* | *80.3* | *208.1* | *3,979* | *1,178* | *100%* | *26,228* | *20,775* | *21%* | *20,775* | *0* |
| 19 | Crop | 0.5 | 1.4 | 1,586 | 377 | 1% | 859 | 204 | 76% | 204 | 0 |
| | Gross | 110.4 | 285.9 | 332 | 277 | 99% | 36,689 | 30,533 | 17% | 30,533 | 0 |
| | *Subtotal* | *110.9* | *287.3* | *1,919* | *654* | *100%* | *37,548* | *30,738* | *18%* | *30,738* | *0* |
| TOTAL | Crop | 1.5 | 3.8 | 1,135 | 274 | 1% | 1,647 | 397 | 76% | | |
| | Urban | 0.2 | 0.6 | 106 | 106 | 0% | 25 | 25 | 0% | | |
| | Gross | 218.0 | 564.6 | 306 | 245 | 99% | 66,739 | 53,356 | 20% | | |
| | ***Subtotal*** | ***219.7*** | ***569.0*** | ***311*** | ***245*** | ***100%*** | ***68,411*** | ***53,778*** | ***21%*** | | |

[1]: based on existing load
[2]: metric tonnes

Table 8-4. TMDLs for Corralitos/Salsipuedes Creek Subwatershed (including Rider Creek)

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load ($t^2$) | TMDL Sediment Load ($t^2$) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Unpaved Road | 0.2 | 0.5 | 4,065 | - | 0% | 785 | - | 100% | - | 0 |
| | Crop | 0.0 | 0.1 | 1,765 | 410 | 0% | 83 | 19 | 77% | 19 | 0 |
| | Forest | 16.0 | 41.5 | 282 | 282 | 50% | 4,528 | 4,526 | 0% | 4,526 | 0 |
| | Mine | 0.0 | 0.0 | 1,530 | 313 | 0% | 12 | 2 | 80% | 2 | 0 |
| | Orchard | 1.9 | 4.9 | 2,386 | 955 | 20% | 4,510 | 1,805 | 60% | 1,805 | 0 |
| | Pasture | 1.3 | 3.3 | 1,423 | 610 | 9% | 1,830 | 784 | 57% | 784 | 0 |
| | Range | 6.9 | 17.9 | 212 | 172 | 13% | 1,464 | 1,185 | 19% | 1,185 | 0 |
| | Barren | 0.0 | 0.1 | 2,661 | 2,661 | 1% | 97 | 97 | 0% | 97 | 0 |
| | Urban | 1.2 | 3.1 | 477 | 477 | 6% | 563 | 563 | 0% | 391 | 172 |
| | Wetland | 0.0 | 0.0 | 1 | 1 | 0% | 0 | 0 | 0% | 0 | 0 |
| | *Subtotal* | *27.6* | *71.5* | *503* | 325 | 100% | *13,872* | *8,982* | *35%* | *8,811* | 172 |
| 4 | Crop | 0.4 | 0.9 | 6,946 | 1,533 | 23% | 2,532 | 559 | 78% | 559 | 0 |
| | Forest | 5.4 | 14.0 | 2 | 2 | 0% | 10 | 10 | 0% | 10 | 0 |
| | Orchard | 0.9 | 2.4 | 3,135 | 1,255 | 48% | 2,901 | 1,161 | 60% | 1,161 | 0 |
| | Pasture | 0.4 | 1.1 | 1,550 | 673 | 12% | 668 | 290 | 57% | 290 | 0 |
| | Range | 14.8 | 38.3 | 14 | 11 | 7% | 210 | 168 | 20% | 168 | 0 |
| | Barren | 0.0 | 0.1 | 1,651 | 1,651 | 2% | 55 | 55 | 0% | 55 | 0 |
| | Urban | 0.8 | 2.0 | 215 | 215 | 7% | 164 | 164 | 0% | 52 | 112 |
| | Wetland | 0.2 | 0.4 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *22.9* | *59.3* | *286* | *105* | *100%* | *6,539* | *2,407* | 63% | *2,295* | *112* |
| TOTAL | Unpaved Road | 0.2 | 0.5 | 4,065 | - | 0% | 785 | - | 100% | | |
| | Crop | 0.4 | 1.1 | 6,353 | 1,404 | 5% | 2,615 | 578 | 78% | | |
| | Forest | 21.4 | 55.5 | 212 | 212 | 40% | 4,538 | 4,536 | 0% | | |
| | Mine | 0.0 | 0.0 | 1,530 | 313 | 0% | 12 | 2 | 80% | | |
| | Orchard | 2.8 | 7.3 | 2,632 | 1,053 | 26% | 7,411 | 2,965 | 60% | | |
| | Pasture | 1.7 | 4.4 | 1,455 | 626 | 9% | 2,499 | 1,074 | 57% | | |
| | Range | 21.7 | 56.2 | 77 | 62 | 12% | 1,674 | 1,354 | 19% | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barren | 0.1 | 0.2 | 2,176 | 2,176 | 1% | 152 | 152 | 0% | | |
| | Urban | 1.9 | 5.0 | 374 | 374 | 6% | 727 | 727 | 0% | | |
| | Wetland | 0.2 | 0.5 | 0 | 0 | 0% | 0 | 0 | 0% | | |
| | ***TOTAL*** | ***50.5*** | *130.8* | ***404*** | ***226*** | ***100%*** | ***20,411*** | *11,389* | ***44%*** | | |

[1]: based on existing load
[2]: metric tonnes

Table 8-5. TMDLs for Rider Creek Subwatershed

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load (t[2]) | TMDL Sediment Load (t[2]) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rider Creek | Forest | 1.2 | 3.1 | 195 | 195 | 80% | 234 | 234 | 0% | 234 | 0 |
| | Range | 0.5 | 1.2 | 153 | 123 | 20% | 73 | 58 | 20% | 58 | 0 |
| | Unpaved Road | 0.0 | 0.0 | 9,382 | - | 0% | 111 | - | 100% | - | 0 |
| | *Subtotal* | ***1.7*** | ***4.4*** | ***248*** | ***174*** | ***100%*** | ***417*** | ***292*** | ***30%*** | ***292*** | ***0*** |

[1]: based on existing load
[2]: metric tonnes

Table 8-6. TMDLs for Llagas Creek Subwatershed

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load (t[2]) | TMDL Sediment Load (t[2]) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Crop | 5.1 | 13.2 | 216 | 44 | 6% | 1,103 | 225 | 80% | 225 | 0 |
| | Forest | 6.0 | 15.7 | 5 | 5 | 1% | 31 | 31 | 0% | 31 | 0 |
| | Mine | 0.0 | 0.0 | 11 | 2 | 0% | 0 | 0 | 80% | 0 | 0 |
| | Orchard | 26.4 | 68.3 | 35 | 14 | 9% | 924 | 369 | 60% | 369 | 0 |
| | Pasture | 4.6 | 11.8 | 23 | 9 | 1% | 104 | 42 | 60% | 42 | 0 |
| | Range | 29.6 | 76.6 | 97 | 78 | 59% | 2,856 | 2,297 | 20% | 2,297 | 0 |
| | Barren | 0.1 | 0.3 | 121 | 121 | 0% | 14 | 14 | 0% | 14 | 0 |
| | Urban | 11.4 | 29.5 | 83 | 83 | 24% | 940 | 940 | 0% | 153 | 787 |
| | Wetland | 0.0 | 0.0 | 0 | 0 | 0% | 0 | 0 | 0% | 0 | 0 |
| | *Subtotal* | *83.2* | *215.5* | *72* | *47* | *100%* | *5,972* | *3,919* | *34%* | *3,132* | *787* |
| 23 | Crop | 0.0 | 0.0 | 4,144 | 1,014 | 0% | 3 | 1 | 76% | 1 | 0 |
| | Forest | 10.8 | 28.0 | 27 | 27 | 6% | 295 | 295 | 0% | 295 | 0 |
| | Orchard | 0.0 | 0.0 | 1,346 | 539 | 0% | 2 | 1 | 60% | 1 | 0 |
| | Pasture | 0.0 | 0.0 | 12,122 | 5,105 | 1% | 66 | 28 | 58% | 28 | 0 |
| | Range | 8.5 | 22.0 | 663 | 542 | 88% | 5,637 | 4,611 | 18% | 4,611 | 0 |
| | Barren | 0.0 | 0.1 | 5,415 | 5,415 | 3% | 130 | 130 | 0% | 130 | 0 |
| | Urban[3] | 0.1 | 0.2 | 3,272 | 3,272 | 4% | 201 | 201 | 0% | 201 | 0 |
| | Wetland | 0.2 | 0.4 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *19.6* | *50.6* | *324* | *269* | *100%* | *6,333* | *5,266* | *17%* | *5,266* | *0* |
| TOTAL | Crop | 5.1 | 13.3 | 216 | 44 | 2% | 1,106 | 226 | 80% | | |
| | Forest | 16.9 | 43.7 | 19 | 19 | 4% | 327 | 327 | 0% | | |
| | Mine | 0.0 | 0.0 | 11 | 2 | 0% | 0 | 0 | 80% | | |
| | Orchard | 26.4 | 68.3 | 35 | 14 | 4% | 926 | 370 | 60% | | |
| | Pasture | 4.6 | 11.8 | 37 | 15 | 1% | 169 | 69 | 59% | | |
| | Range | 38.1 | 98.6 | 223 | 182 | 75% | 8,493 | 6,908 | 19% | | |
| | Barren | 0.1 | 0.4 | 1,020 | 1,020 | 2% | 144 | 144 | 0% | | |
| | Urban | 11.5 | 29.7 | 100 | 100 | 12% | 1,141 | 1,141 | 0% | | |
| | Wetland | 0.2 | 0.4 | 0 | 0 | 0% | 0 | 0 | 0% | | |
| | ***TOTAL*** | ***102.7*** | ***266.1*** | ***120*** | ***89*** | ***100%*** | ***12,306*** | ***9,185*** | ***25%*** | | |

[1]: based on existing load; [2]: metric tonnes; [3]: Occurs outside a designated "urban boundary"; therefore not a WLA

Table 8-7. TMDLs for Uvas Creek Subwatershed

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load (t[2]) | TMDL Sediment Load (t[2]) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Crop | 1.1 | 2.8 | 1,390 | 289 | 5% | 1,479 | 307 | 79% | 307 | 0 |
| | Forest | 24.2 | 62.6 | 13 | 13 | 5% | 304 | 304 | 0% | 304 | 0 |
| | Mine | 0.0 | 0.0 | 177 | 38 | 0% | 2 | 0 | 79% | 0 | 0 |
| | Orchard | 3.5 | 9.0 | 460 | 184 | 10% | 1,598 | 639 | 60% | 639 | 0 |
| | Pasture | 2.3 | 5.9 | 406 | 163 | 6% | 933 | 375 | 60% | 375 | 0 |
| | Range | 22.7 | 58.8 | 255 | 208 | 70% | 5,790 | 4,710 | 19% | 4,710 | 0 |
| | Barren | 0.1 | 0.3 | 615 | 615 | 1% | 61 | 61 | 0% | 61 | 0 |
| | Urban | 1.1 | 2.8 | 317 | 317 | 5% | 348 | 348 | 0% | 209 | 139 |
| | Wetland | 0.0 | 0.0 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *54.9* | *142.2* | *191* | *123* | | *10,514* | *6,744* | 36% | *6,605* | 139 |
| 22 | Forest | 22.1 | 57.2 | 31 | 31 | 8% | 685 | 685 | 0% | 685 | 0 |
| | Range | 9.5 | 24.5 | 943 | 778 | 87% | 8,931 | 7,369 | 17% | 7,369 | 0 |
| | Barren | 0.0 | 0.1 | 6,385 | 6,385 | 4% | 308 | 308 | 0% | 308 | 0 |
| | Urban[3] | 0.0 | 0.1 | 3,221 | 3,221 | 1% | 71 | 71 | 0% | 71 | 0 |
| | Wetland | 0.2 | 0.6 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *31.8* | *82.5* | *314* | *265* | | *9,995* | *8,433* | 16% | 8,433 | 0 |
| TOTAL | Crop | 1.1 | 2.8 | 1,390 | 289 | 2% | 1,479 | 307 | 79% | | |
| | Forest | 46.2 | 119.7 | 21 | 21 | 7% | 989 | 989 | 0% | | |
| | Mine | 0.0 | 0.0 | 177 | 38 | 0% | 2 | 0 | 79% | | |
| | Orchard | 3.5 | 9.0 | 460 | 184 | 4% | 1,598 | 639 | 60% | | |
| | Pasture | 2.3 | 5.9 | 406 | 163 | 2% | 933 | 375 | 60% | | |
| | Range | 32.2 | 83.3 | 458 | 376 | 80% | 14,721 | 12,079 | 18% | | |
| | Barren | 0.1 | 0.4 | 2,513 | 2,513 | 2% | 369 | 369 | 0% | | |
| | Urban | 1.1 | 2.9 | 374 | 374 | 3% | 419 | 419 | 0% | | |
| | Wetland | 0.2 | 0.6 | - | - | 0% | - | - | 0% | | |
| | ***TOTAL*** | ***86.7*** | ***224.7*** | ***236*** | ***175*** | ***100%*** | ***20,508*** | ***15,177*** | 26% | | |

[1]: based on existing load; [2]: metric tones; [3] Occurs outside a designated "urban boundary"; therefore associated load is LA

Table 8-8. TMDLs for Upper Pajaro (Pacheco Creek)

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load (t[2]) | TMDL Sediment Load (t[2]) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Forest | 26.3 | 68.2 | 20 | 20 | 4% | 536 | 536 | 0% | 536 | 0 |
| | Range | 40.6 | 105.1 | 358 | 290 | 96% | 14,545 | 11,775 | 19% | 11,775 | 0 |
| | Wetland | 0.1 | 0.1 | 0 | 0 | 0% | 0 | 0 | 0% | 0 | 0 |
| | *Subtotal* | *67.0* | *173.5* | *225* | *184* | *100%* | *15,081* | *12,311* | 18% | 12,311 | 0 |
| 2 | Crop | 0.0 | 0.0 | 422 | 85 | 0% | 0 | 0 | 80% | 0 | 0 |
| | Forest | 9.1 | 23.5 | 26 | 26 | 4% | 234 | 234 | 0% | 234 | 0 |
| | Range | 18.5 | 47.9 | 419 | 339 | 95% | 7,749 | 6,276 | 19% | 6,276 | 0 |
| | Urban[3] | 0.1 | 0.2 | 1,370 | 1,370 | 2% | 102 | 102 | 0% | 102 | 0 |
| | *Subtotal* | *27.6* | *71.6* | *292* | *239* | *100%* | *8,085* | *6,612* | 18% | 6,612 | 0 |
| 10 | Crop | 1.4 | 3.6 | 1,980 | 430 | 5% | 2,752 | 597 | 78% | 597 | 0 |
| | Forest | 26.4 | 68.5 | 16 | 16 | 3% | 418 | 418 | 0% | 418 | 0 |
| | Orchard | 3.7 | 9.5 | 602 | 241 | 7% | 2,199 | 880 | 60% | 880 | 0 |
| | Pasture | 4.5 | 11.6 | 1,989 | 853 | 30% | 8,910 | 3,821 | 57% | 3,821 | 0 |
| | Range | 34.0 | 88.1 | 247 | 199 | 53% | 8,417 | 6,789 | 19% | 6,789 | 0 |
| | Barren | 0.1 | 0.2 | 2,004 | 2,004 | 1% | 140 | 140 | 0% | 140 | 0 |
| | Urban[3] | 0.5 | 1.4 | 319 | 319 | 1% | 175 | 175 | 0% | 175 | 0 |
| | Wetland | 0.0 | 0.0 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *70.6* | *182.9* | *326* | *182* | *100%* | *23,012* | *12,820* | 44% | 12,820 | 0 |
| TOTAL | Crop | 1.4 | 3.6 | 1,979 | 430 | 2% | 2,752 | 598 | 78% | | |
| | Forest | 61.8 | 160.2 | 19 | 19 | 4% | 1,187 | 1,187 | 0% | | |
| | Orchard | 3.7 | 9.5 | 602 | 241 | 3% | 2,199 | 880 | 60% | | |
| | Pasture | 4.5 | 11.6 | 1,989 | 853 | 12% | 8,910 | 3,821 | 57% | | |
| | Range | 93.1 | 241.2 | 330 | 267 | 78% | 30,711 | 24,840 | 19% | | |
| | Barren | 0.1 | 0.2 | 2,004 | 2,004 | 0% | 140 | 140 | 0% | | |
| | Urban | 0.6 | 1.6 | 445 | 445 | 1% | 277 | 277 | 0% | | |
| | Wetland | 0.1 | 0.2 | 0 | 0 | 0% | 0 | 0 | 0% | | |
| | ***TOTAL*** | ***165.2*** | ***428.0*** | ***279*** | ***192*** | ***100%*** | ***46,178*** | ***31,742*** | ***31%*** | | |

[1]: based on existing load; [2]: metric tones; [3] Occurs outside a designated "urban boundary"; therefore associated load is LA

Table 8-9. TMDLs for Upper Pajaro (Santa Ana Creek)

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load (t[2]) | TMDL Sediment Load (t[2]) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Crop | 7.4 | 19.2 | 1,292 | 276 | 17% | 9,593 | 2,052 | 79% | 2,052 | 0 |
| | Forest | 11.9 | 30.9 | 3 | 3 | 0% | 40 | 40 | 0% | 40 | 0 |
| | Mine | 0.1 | 0.2 | 196 | 41 | 0% | 15 | 3 | 79% | 3 | 0 |
| | Orchard | 2.7 | 7.0 | 544 | 218 | 5% | 1,463 | 585 | 60% | 585 | 0 |
| | Pasture | 25.5 | 66.0 | 630 | 258 | 54% | 16,063 | 6,585 | 59% | 6,585 | 0 |
| | Range | 68.3 | 176.8 | 44 | 35 | 20% | 3,002 | 2,418 | 19% | 2,418 | 0 |
| | Barren | 0.7 | 1.8 | 413 | 413 | 2% | 285 | 285 | 0% | 285 | 0 |
| | Urban | 3.8 | 9.9 | 63 | 63 | 2% | 240 | 240 | 0% | 79 | 161 |
| | Wetland | 0.0 | 0.0 | - | - | 0% | - | - | 0% | - | 0 |
| | ***TOTAL*** | ***120.4*** | ***311.8*** | ***255*** | ***101*** | ***100%*** | ***30,701*** | ***12,208*** | **60%** | **12,048** | **161** |

[1]: based on existing load
[2]: metric tones

Table 8-10. TMDLs for Lower Pajaro

| Modeled Subbasin | LANDUSE | AREA (sq mile) | AREA (sq km) | Existing Sediment Load Rate (t/sq mile/yr) | TMDL Sediment Load Rate (t/sq mile/yr) | % Contribution to Sediment Load [1] | Existing Sediment Load (t[2]) | TMDL Sediment Load (t[2]) | % Reduction | LA | WLA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Crop | 6.1 | 15.9 | 97 | 20 | 44% | 597 | 121 | 80% | 121 | 0 |
| | Forest | 0.1 | 0.3 | 1 | 1 | 0% | 0 | 0 | 0% | 0 | 0 |
| | Orchard | 2.1 | 5.4 | 46 | 18 | 14% | 96 | 38 | 60% | 38 | 0 |
| | Pasture | 7.8 | 20.2 | 17 | 7 | 20% | 136 | 55 | 60% | 55 | 0 |
| | Range | 5.5 | 14.3 | 10 | 8 | 15% | 52 | 42 | 20% | 42 | 0 |
| | Barren | 0.2 | 0.4 | 39 | 39 | 2% | 6 | 6 | 0% | 6 | 0 |
| | Urban | 0.2 | 0.5 | 48 | 48 | 4% | 10 | 10 | 0% | 8 | 2 |
| | Wetland | 0.0 | 0.0 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *22.0* | *57.1* | *41* | *12* | *100%* | *898* | *272* | *70%* | *270* | *2* |
| 7 | Crop | 1.2 | 3.0 | 673 | 146 | 35% | 775 | 168 | 78% | 168 | 0 |
| | Forest | 0.2 | 0.4 | 1 | 1 | 0% | 0 | 0 | 0% | 0 | 0 |
| | Orchard | 0.7 | 1.9 | 436 | 174 | 27% | 325 | 130 | 60% | 130 | 0 |
| | Pasture | 0.7 | 1.8 | 190 | 77 | 11% | 131 | 53 | 60% | 53 | 0 |
| | Range | 1.6 | 4.2 | 8 | 6 | 2% | 12 | 10 | 20% | 10 | 0 |
| | Barren | 0.1 | 0.2 | 443 | 443 | 6% | 30 | 30 | 0% | 30 | 0 |
| | Urban | 1.5 | 4.0 | 62 | 62 | 20% | 95 | 95 | 0% | 11 | 84 |
| | Wetland | 0.2 | 0.4 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *6.1* | *15.8* | *224* | *80* | *100%* | *1,368* | *486* | *65%* | *401* | *84* |
| 8 | Crop | 6.3 | 16.3 | 977 | 212 | 39% | 6,151 | 1,334 | 78% | 1,334 | 0 |
| | Forest | 3.6 | 9.4 | 0 | 0 | 0% | 2 | 2 | 0% | 2 | 0 |
| | Mine | 0.2 | 0.4 | 998 | 205 | 1% | 169 | 35 | 79% | 35 | 0 |
| | Orchard | 2.7 | 6.9 | 690 | 276 | 21% | 1,830 | 732 | 60% | 732 | 0 |
| | Pasture | 4.1 | 10.5 | 336 | 137 | 16% | 1,365 | 557 | 59% | 557 | 0 |
| | Range | 11.8 | 30.7 | 4 | 3 | 1% | 50 | 40 | 20% | 40 | 0 |
| | Barren | 0.6 | 1.5 | 636 | 636 | 11% | 372 | 372 | 0% | 372 | 0 |
| | Urban | 1.3 | 3.3 | 289 | 289 | 11% | 371 | 371 | 0% | 302 | 69 |
| | Wetland | 0.0 | 0.1 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *30.6* | *79.1* | *337* | *113* | *100%* | *10,311* | *3,443* | *67%* | *3,374* | *69* |
| 12 | Crop | 2.9 | 7.4 | 159 | 32 | 52% | 456 | 93 | 80% | 93 | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forest | 0.1 | 0.3 | 0 | 0 | 0% | 0 | 0 | 0% | 0 | 0 |
| | Orchard | 1.0 | 2.6 | 75 | 30 | 17% | 75 | 30 | 60% | 30 | 0 |
| | Pasture | 3.8 | 9.8 | 29 | 12 | 25% | 110 | 44 | 60% | 44 | 0 |
| | Range | 1.0 | 2.6 | 8 | 6 | 3% | 8 | 6 | 20% | 6 | 0 |
| | Barren | 0.0 | 0.1 | 12 | 12 | 0% | 0 | 0 | 0% | 0 | 0 |
| | Urban[3] | 0.1 | 0.3 | 45 | 45 | 3% | 6 | 6 | 0% | 6 | 0 |
| | *Subtotal* | *8.9* | *23.1* | *73* | *20* | *100%* | *655* | *179* | *73%* | *179* | *0* |
| 13 | Crop | 4.0 | 10.4 | 182 | 37 | 50% | 728 | 149 | 80% | 149 | 0 |
| | Forest | 0.3 | 0.7 | 0 | 0 | 0% | 0 | 0 | 0% | 0 | 0 |
| | Orchard | 0.0 | 0.1 | 605 | 242 | 3% | 24 | 10 | 60% | 10 | 0 |
| | Pasture | 2.9 | 7.5 | 39 | 16 | 16% | 114 | 46 | 60% | 46 | 0 |
| | Range | 0.7 | 1.8 | 6 | 5 | 1% | 4 | 3 | 20% | 3 | 0 |
| | Barren | 0.1 | 0.2 | 281 | 281 | 9% | 25 | 25 | 0% | 25 | 0 |
| | Urban | 0.8 | 2.2 | 74 | 74 | 21% | 62 | 62 | 0% | 26 | 36 |
| | Wetland | 0.1 | 0.2 | - | - | 0% | - | - | 0% | - | 0 |
| | *Subtotal* | *8.9* | *23.0* | *108* | *33* | *100%* | *958* | *295* | *69%* | *259* | *36* |
| 14 | Crop | 1.1 | 2.8 | 940 | 205 | 35% | 1,032 | 225 | 78% | 225 | 0 |
| | Forest | 0.3 | 0.9 | 3 | 3 | 0% | 1 | 1 | 0% | 1 | 0 |
| | Orchard | 0.0 | 0.1 | 645 | 258 | 2% | 25 | 10 | 60% | 10 | 0 |
| | Pasture | 1.2 | 3.1 | 608 | 248 | 46% | 724 | 295 | 59% | 295 | 0 |
| | Range | 4.5 | 11.5 | 24 | 19 | 14% | 108 | 87 | 20% | 87 | 0 |
| | Barren | 0.0 | 0.0 | 449 | 449 | 1% | 7 | 7 | 0% | 7 | 0 |
| | Urban[3] | 0.1 | 0.3 | 188 | 188 | 3% | 18 | 18 | 0% | 18 | 0 |
| | *Subtotal* | *7.2* | *18.8* | *265* | *89* | *100%* | *1,916* | *643* | *66%* | *643* | *0* |
| 24 | Crop | 0.0 | 0.1 | 1,522 | 322 | 0% | 34 | 7 | 79% | 7 | 0 |
| | Forest | 5.6 | 14.5 | 10 | 10 | 3% | 55 | 55 | 0% | 55 | 0 |
| | Pasture | 0.2 | 0.5 | 547 | 221 | 2% | 109 | 44 | 60% | 44 | 0 |
| | Range | 8.4 | 21.7 | 257 | 212 | 91% | 2,156 | 1,773 | 18% | 1,773 | 0 |
| | Barren | 0.0 | 0.1 | 2,086 | 2,086 | 3% | 60 | 60 | 0% | 60 | 0 |
| | Urban[3] | 0.2 | 0.5 | 64 | 64 | 1% | 12 | 12 | 0% | 12 | 0 |
| | *Subtotal* | *14.4* | *37.4* | *168* | *135* | *100%* | *2,425* | *1,951* | *20%* | *1,951* | *0* |
| TOTAL | Crop | 21.6 | 55.8 | 453 | 97 | 29% | 9,773 | 2,096 | 79% | | |
| | Forest | 10.2 | 26.5 | 6 | 6 | 1% | 58 | 58 | 0% | | |
| | Mine | 0.2 | 0.4 | 998 | 205 | 0% | 169 | 35 | 79% | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Orchard | 6.6 | 17.0 | 362 | 145 | 13% | 2,375 | 950 | 60% | |
| | Pasture | 20.7 | 53.5 | 130 | 53 | 15% | 2,690 | 1,094 | 59% | |
| | Range | 33.5 | 86.7 | 71 | 59 | 27% | 2,391 | 1,962 | 18% | |
| | Barren | 1.0 | 2.5 | 516 | 516 | 7% | 500 | 500 | 0% | |
| | Urban | 4.3 | 11.1 | 134 | 134 | 8% | 574 | 574 | 0% | |
| | Wetland | 0.3 | 0.7 | - | - | 0% | - | - | 0 | |
| | ***TOTAL*** | ***98.2*** | ***254.3*** | ***189*** | ***74*** | ***100%*** | ***18,530*** | ***7,268*** | 61% | |

[1]: based on existing load
[2]: metric tonnes
[3] Occurs outside a designated "urban boundary"; therefore associated load is LA

# 9.0 IMPLEMENTATION

Regional Board to provide text.

SanBenito and Tres Pinos : Rangeland management practices guidelines—use plan as part of the implementation piece (cattle impacts, though limited, may be present here).

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